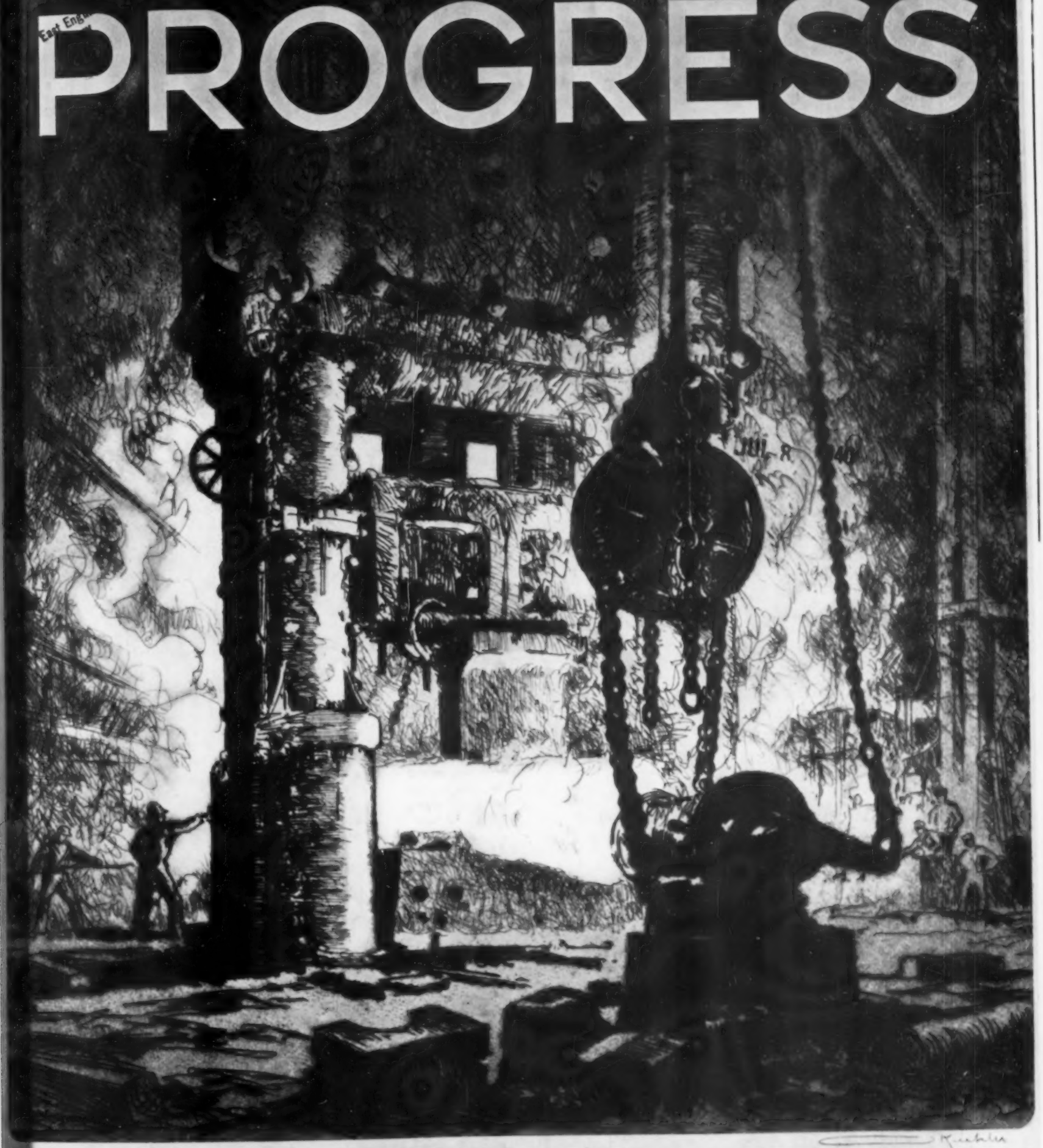
JULY

METAL PROGRESS

1940



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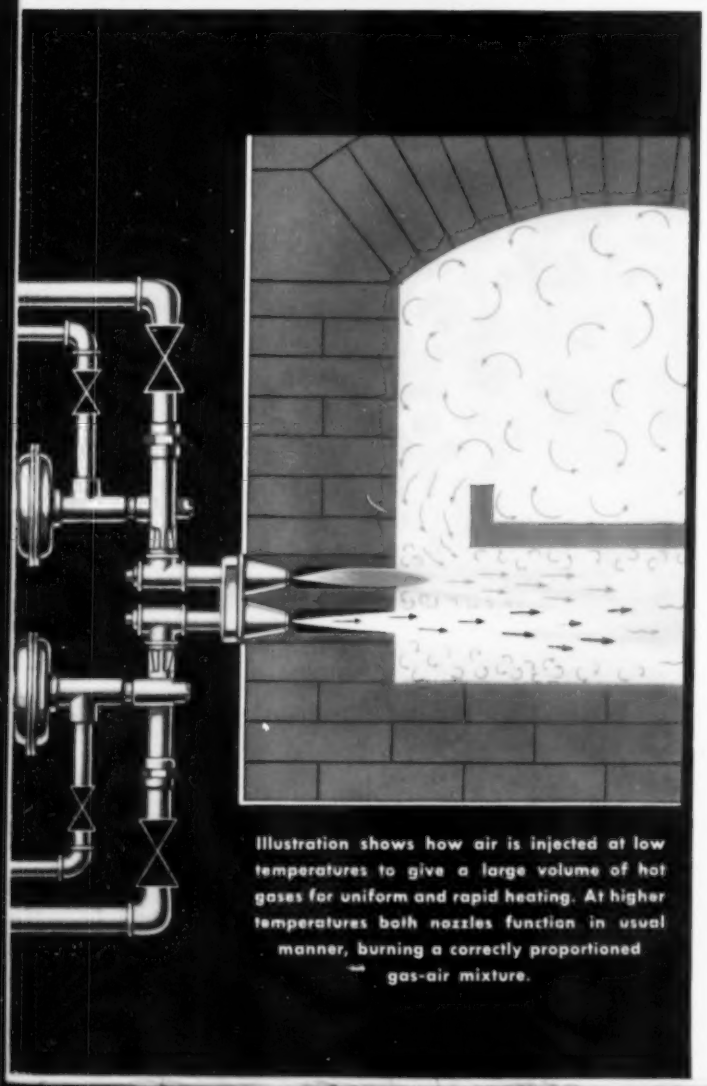

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METAL PROGRESS

July, 1940 **Vol. 38 No. 1**

TABLE OF CONTENTS

Cover is a half-tone engraving of an etching by Otto Kuhler

Critical Points by the Editor 33
Satisfactory Valve Spring Wire Made in America
New Mill for Electric Alloy Steel
Forming-Dies for Duralumin Sheet, Made of Cast Zinc
Stress Relief of Heavy Steel Weldings .... Boilers for 2650 Psi.
Alloy Malleable, Fully Graphitized, Has High Yield Point
Notes on Cartridge Brass and Small Arms

Steel Rails in the United States; a Review of Developments 36
by H. H. Morgan

Fabrication of Stainless Steel Into Chemical & Process Vessels .. 39
by Philip L. Coddington

Sorby's Pioneering Work on the Microstructure of Rocks and Metals 45
by J. H. G. Monypenny

Operations on the Pit Side of a Modern Openhearth 49
by G. D. Tranter

High Surface Finishes — Their Preparation, Specification and Effect on Wear and Fatigue 54
A report by Russell W. Dayton of Conferences on Friction and Surface Finish, June 5 to 7, at Massachusetts Institute of Technology

Welded Connections for Tier Buildings 57
Data Sheet

Static Crack Strength of Metals; Its Determination and Significance 59
by Maxwell Gensamer

Mechanical Effects of Grain Boundaries 64
by Martin Seyt

Correspondence
Toughness of Toolsteels, by Nathan Levinsohn 66
Reply by Robert S. Rose 67
Names for Steel's Microconstituents, by Nicolas T. Belaiew 68
High Speed Impact Testing, by N. Davidenkoff 69
The Forgeability of Steels, by Albert M. Portevin 70
Austempering Improves Valve Springs, by Alberto Oreffice 71

Personal News, Largely Movements of A.S.M. Members 72, 74

Progress in Electro-Galvanizing 76
by J. A. Singmaster; Extracts from an address to the American Zinc Institute, April 30, 1940

Literature Produced by Advertisers, Free to Readers .. 90, 92, 94

Biographical Notes and Portraits of Contributors 102

Index of Firms Who Are Advertising 114

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METAL PROGRESS

VOL. 38 JULY, 1940 NO. 1

CRITICAL POINTS

By the Editor

WHAT ABOUT valve spring wire, now that imports of that popular and excellent Swedish carbon steel are shut off? Well, we don't need to worry as far as aircraft engines are concerned, for the last springs made from carbon steel or music wire were made at least ten years ago. Valve springs on air-cooled engines run so hot that carbon steel springs "set" slightly, and so an alloy steel became a practical necessity. American supplies have been developed for this critical service, demanding a quite superior grade of electric furnace S.A.E. 6150 chrome-vanadium steel, absolutely free from surface decarburization and mechanical defects.

satisfactory valve spring wire, made in America

The Swedish carbon steel wire has been standard for valve springs in automobile, truck, tractor and gas engines, and while it is wire with excellent surface the reason for preference over American wire is not so much quality as price. Price of Swedish steel fluctuates not with conditions in Sweden but in America, always pegged a certain amount below what an equivalent American wire can be bought for. Important makers of high grade springs have recognized the danger of such a situation, and for several years have been working with cooperative wire mills to remedy it, although two of the big three automobile manufacturers have insisted that springs of American made steel must cost no more than those made of foreign steel. The result is that excellent American spring wire has been available for some months, is being furnished in a growing proportion of current orders going to large automobile makers, and the latter are becoming acquainted with the new material in their springs and finding that it has the same fatigue strength and service life. Consequently while Swedish stocks on hand will probably be sufficient for 1940 automobile models, and at least one firm is protected for a year longer, other builders of gas engines can be assured that American carbon steel can be secured of consistently high quality, equal to what they have been getting in the past, without the necessity of paying the alloy extra for 6150 steel.

TO WARREN, Ohio, where Copperweld Steel Co. has assembled a notable staff — headed by FRED GRIFFITHS, dean of alloy steel makers — to build and operate a mill exclusively for "Aristoloy" electric steel billets and bars. (The copperweld or copper-clad wire is still made in its mill at Glassport, Pa.) Notable about the design and layout of the mill is the avoidance of pits and cellars; even the soaking "pits" are large, box-like structures like the heating furnaces in a heavy forge shop. The melting shop contains two three-phase electric arc furnaces made by Swindell-Dressler, of 25-ton nominal and 30-ton actual capacity, as well as one 6-ton furnace for small orders of special steels. Roofs and electrode supports can be raised and swung aside so the open furnaces are filled by drop-bottom buckets each holding about half the charge. The bottom of the charging bucket is closed by six "orange-peel" segments, hinged at the edges but tied at their center with a loop of rope; when the rope burns away the charge drops, clump! Ingots are of one standard size and shape, cast big end up with refractory tops into fluted rounds weighing about a ton — a size that avoids installing a heavy blooming mill.

new mill for electric alloy steel

The casting bay is especially convenient; there are five elevated platforms and four long double rows of 30 molds between them. Platforms are wide enough to hold rows of hot-top stands. Teeming into ingot molds on fixed stools is from a large ladle with double nozzles. W. J. (BILL) BUECHLING, chief metallurgist, emphasized the careful ingot mold preparation and teeming practice, all of which pays dividends in lower chipping costs. Cleanest and coolest building houses the works office, chemical laboratory and metallurgical department, amply staffed and equipped (even to the convenience of a freight elevator) to keep the quality of the steel up to its trade name.

POSSIBLY PROMPTED by REID GRAY's letter in the May issue on die manufacture for duralumin aircraft sheathing and structural members, an inquiry came to the Editor's desk (supposedly the seat of learning) about the analysis of the alloys so used — an inquiry answerable only after a canvass had been made of ASMembers in the aircraft industry. If you are interested in the answer here it is: The "dies" in question are the aircraft industry's equivalent to the alloy iron dies used for stamping sheet steel into refrigerator boxes and what have you. Most plants started out with dies for short runs, say 20 to 50 parts, and used "Prime Western", or purer brands of slab zinc. Prime Western is rather soft, but it is cheap. Remelting of obsolete and worn dies will contaminate the metal with iron from the pots, antimonial lead from the dies forming the "punches", and aluminum from general plant scrap, so that the casting temperature gradually rises from 800 to around 950° F. Iron contamination is excessive, even from alloy cast iron melting pots, at temperatures above 900° F., and this is thought to cause surface crinkles called "dural bug marks" on the West Coast. Zinc alloys, such as those developed for die castings, are several times as strong, hard and tough as slab zinc, and are capable of forming accurately at least 15 times as many stampings, so alloyed zinc is adopted when production goes up. New Jersey Zinc's "Zamak" No. 2 and No. 5 are favored (respectively A.S.T.M. specification B86-38T Alloy No. 21 and 25 respectively); the former has about 4% aluminum, 3% copper and 0.05% magnesium; in the latter the copper is only 1%. Their successful re-use requires better housekeeping around the die foundry, but these alloys cast readily and soundly at around 800° F. — in fact, overheating should be carefully avoided — and the result is an accurately reproduced surface requiring but little polishing if the plaster of paris mold is well made. One friend writes that the Germans, who seem to know how to make plenty of aircraft, use 5% copper in zinc rather than aluminum, believing this alloy is less damaged by normal contaminations, but this is contrary to the usual belief that aluminum reduces scour on the pots. One important American builder successfully reclaims scrap aluminum collected around the plant for casting both punches and dies for hydraulic press work. Most West Coast plants use "Kirksite A", a slightly modified Zamak No. 2 for a harder die when cast in sand, promoted by Morris P. Kirk & Son of Los Angeles.

forming-dies for duralumin sheet, made of cast zinc

TO A well-attended conference sponsored by the American Welding Society and heard GEORGE JESSOP, chief engineer of S. Morgan Smith Co. of York, Pa., tell of the manufacture of enormous hydraulic turbines each capable of developing 74,000 h.p. In them "light plate" means 1 in. thick. Many large subdivisions of these machines, which are ordered one or two to a special design, may be welded of steel plate in about the same time it would take a foundry to build the pattern. Pieces prior to machining, and of sizes limited only by railroad clearances, are shipped to nearby firms for annealing in stress relieving furnaces. . . . . If any doubts remain of the necessity for this expensive heat treatment they would be resolved by JAMES HODGE's accounts of two accidents to unannealed parts of the huge penstocks for Boulder Dam. These were large cylindrical sections or rings, and so should be able to relieve their internal stresses relatively easily, yet one penstock section cracked on being dropped 18 in., and a reinforcing ring broke of its own weight while being moved. Another penstock section was accidentally dropped far enough to dent it badly, but, being stress relieved, no fractures occurred. Tests indicate that more internal stresses are induced by the greater the number of passes in arc welding thick plate; single pass welding with heavy currents and large heat inputs is therefore preferable. Defects similar to flakes in forgings are likely to infest multi-

stress relief of heavy steel weldings

pass joints, and greatly reduce their longitudinal ductility, unless the entire joint is kept warm (at 150 to 200° F.) until welding is completed. . . . . Dr. HODGE, who as everyone knows, is the chief metallurgist for Babcock & Wilcox Co., a pioneer and international authority on the welding of pressure vessels, also approved Mr. JESSOP's thought that by welding one can do many things otherwise impossible (or at least do them much more extensively). He said that by 1929, the thickest plate rivetable into the 750-psi. steam drums then under construction was 2⅞ in. Now a 220-psi. drum is in service, 48 in. inside diameter, welded of 6⅝-in. plate (8½ in. thick rings at the openings) and a boiler drum to hold 2650 psi. of steam pressure is under construction.

boilers for 2650 psi.

LEARNED from LEON WISE, manager of research and development for Chicago Malleable Castings Co., some of the progress that has been made in bridging the gap between plain malleable iron and carbon steel castings. Plain malleable has been improved consistently through the years, without changing its essential composition and typical microstructure, by greater care in the foundry details — that is, by making the average production closer to the ideal best, a ceiling limited by the properties of the ferrite forming the groundmass of the material. Beyond that point the ferrite may be strengthened by alloying with some element that goes into solid solution, or by leaving a little carbon behind after annealing — in other words, either by making an "alloy malleable" or a "pearlitic malleable". WISE's firm favors the former for its easy machinability, among other things, and is making a considerable tonnage of castings for several users in the railroad equipment and machinery industries. Tensile strengths of 62,000 psi. are intermediate between plain malleable and carbon steel castings; yield points averaging 45,000 psi. are high even for soft steel castings (hence the trade name Super-Y — "Y" for yield); elongations of 18 to 20% in 2 in. are no lower than the better grade of regular malleable. Costs are a little larger, due to the alloys consumed, but progress is represented in a new level of cast metals, nearly as strong and tough as mild steel, as machinable as plain malleable, and as smooth as gray iron.

alloy malleable, fully graphitized, has high yield

DID YOU KNOW that the Civil War was fought largely with muzzle loaders, and that about 60 different types and calibers of muskets and other small arms (including flintlocks) were used at the battle of Gettysburg, despite the fact that the essential elements of a Winchester breech-loading rifle had been invented and marketed in America as early as 1852? The early breech-loading weapon was a lever-action, repeating pistol with a pat name, the "Volcanic", for the bullet had a cavity in its base filled with fulminate; if enough fulminate was there to propel the bullet any distance, it exploded the breech! . . . . This and a lot of other interesting information of the sort was told by HERBERT MOULTON, president of the American Institute of Mining and Metallurgical Engineers, to the Cleveland Section, and he had samples to prove it. The point of his story was that even though the essential mechanism for an improved rifle was known, and the need for it was great, it took at least 20 years for it to succeed, for it took that long to develop a prime essential — reliable cartridge brass. The metal cartridge must expand instantly against the breech bore when the powder explodes, to form a gas tight seal against back fire ("obturation" is the ballistic term), and as quickly spring back so the empty shell can be extracted. Soft copper does not spring back. Resilient brass, as he said, was not regularly produced for 20 years after the need was known. The earlier cartridges would often stick just when the need for quick reloading was most acute. Hence the Indian fighters (and MOULTON's father was one) favored the Sharp's rifle and the single-action Colt's revolver, for the first of these had a toggle-lever ejector powerful enough to pull a sticky cartridge out, and the Colt had a side-attached ramrod that could be hammered back as a persuader. Ability to remove surely any empty cartridge therefore favored the .44-caliber Sharp's rifle with .44-90 ammunition (90 grains of black powder made it a murderous projectile). The early Winchester carbine, on the other hand, had an ejector that could not cope with an expanded cartridge so about 40 grains of powder was all that could safely be used. [P.S. The Colt .44-40 six-shooter was often used instead of the more popular .45 because it used the same ammunition as the carbine, and the cowboy and frontiersman often carried both weapons.]

notes on cartridge brass and small arms

STEEL RAILS IN THE U. S.

A REVIEW OF DEVELOPMENTS

By H. H. Morgan
Mgr., Rail & Fastenings Dept.
Robert W. Hunt Co., Engineers
Chicago

SEVENTY-FIVE years ago, on May 24 and 25, 1865, the North Chicago Rolling Mills rolled the first steel rails made in this country. It was an experimental rolling of converter steel made at the Wyandotte Iron Works, just outside of Detroit. (Wyandotte had the first successful tilting converter, built under patents awarded to the American, WILLIAM KELLEY, a fact commemorated by a bronze tablet erected in 1922 on the site by the Detroit Chapter ⚙.) The first *commercial* rolling did not occur until August 1867 when the Cambria Iron Co. in Johnstown, Pa., executed an order of 57-lb. rails for one of the eastern railroads. This steel was made at the Pennsylvania Steel Co.'s bessemer plant at Steelton, Pa.

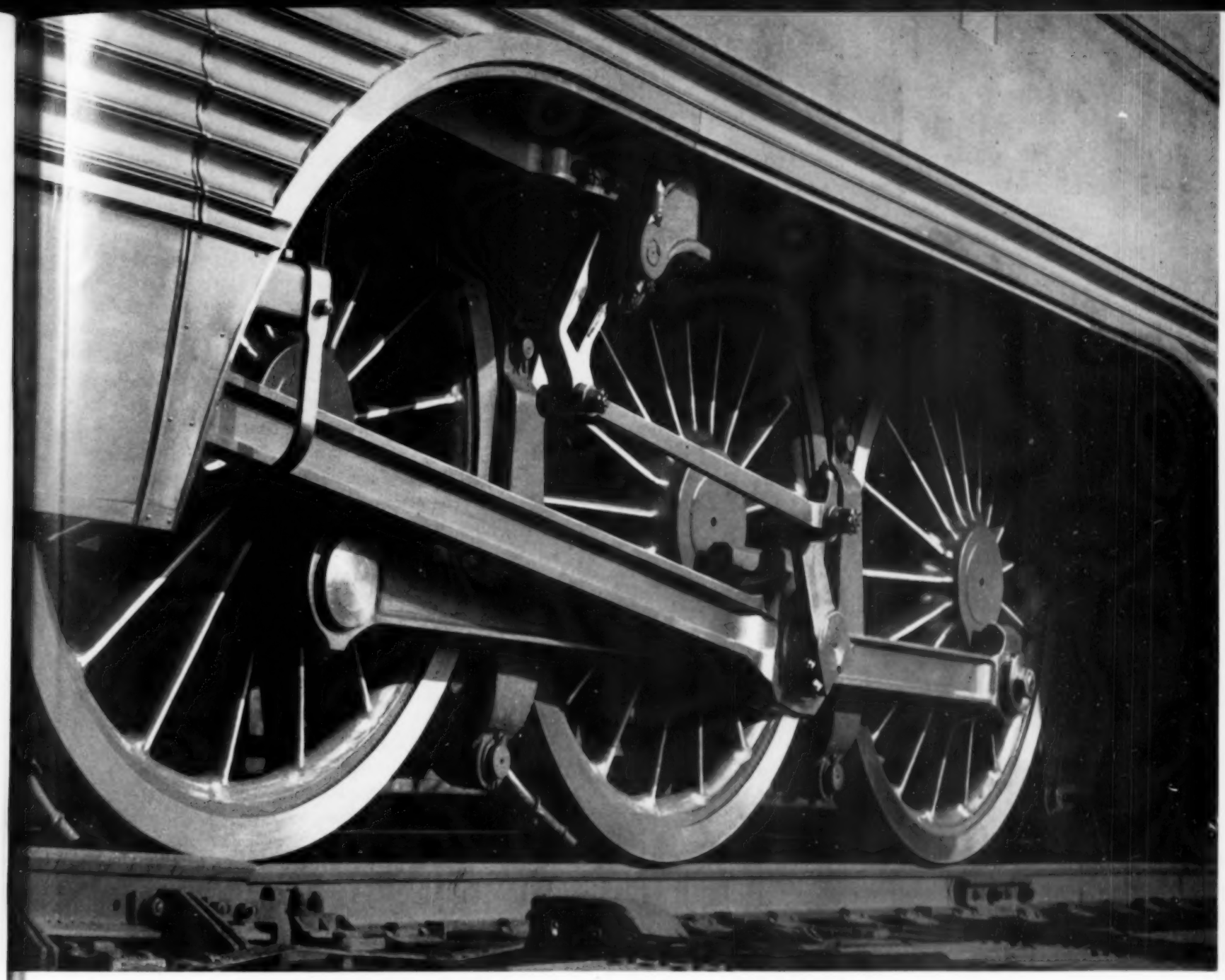
The manufacture of bessemer steel into rails progressed rapidly as experience with the first American-made rails and similar rails imported from abroad, commencing late in 1863, showed results so superior to the earlier iron rails. An outline of subsequent events follows. (In this brief review of the development of rail steel since its first use in the United States, I am using approximate dates which may be subject to challenge.)

In the iron rail days the rails were small, sometimes running up to 50 and 60 lb. per yd., and they were rolled in all types of sections. There were as many as 900 regularly used sections at one time! Seemingly every railroad man had his own ideas as to the proper shape, and he could always find some small maker of puddled iron to roll it for him.

There were relatively few plants making bessemer steel, and this fact rapidly reduced the number of mills capable of producing rails. Roll costs soared and turned the industry's attention to the need of some sort of standardization. This, however, took a quarter of a century, and it was not until 1893 that the American Society of Civil Engineers adopted its list of standard sections for railroad rails.

The rapid development of the country caused a corresponding increase in axle loads and size of motive power. These changes placed heavier demands upon the bessemer steel rail, even though sections were increased to 75 and 80 lb. per yd. In 1907, new sections with heavier flanges, called American Railway Association Sections "A" and "B", were added to the former standards. They had unprecedented weights, up to 100 lb. per yd.

In the meantime, a very important change



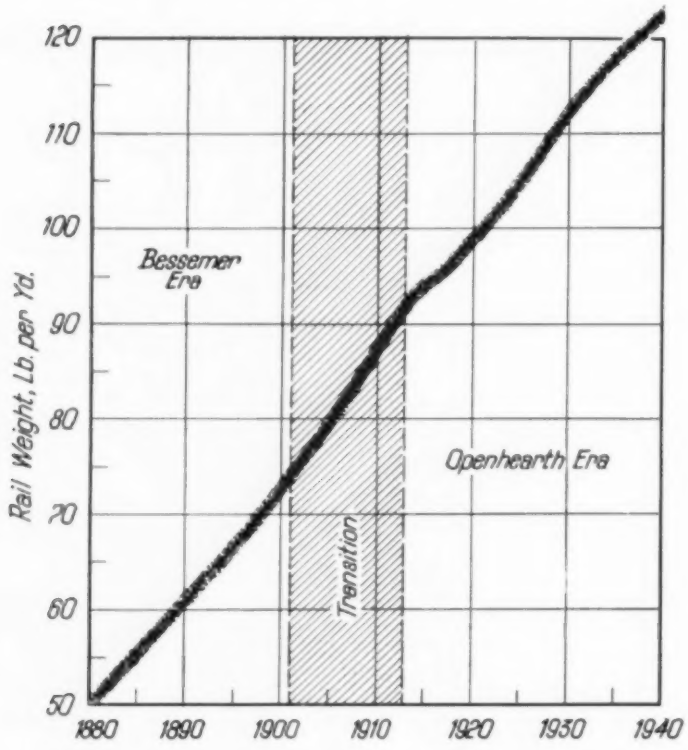
Heavy Traffic at High Speed Requires Safe and Durable Rail

Photograph by William M. Rittase for Reading Railroad

was being made in the kind of steel available for rails. The production of openhearth steel in this country had commenced in 1870. There is no positive record of when the first openhearth rail steel was rolled, but it is probable that an occasional small heat of acid openhearth steel was rolled into rail sometime in the 80's. The first openhearth rails on an experimental railroad order were made in the late 90's at the South Works of the Illinois Steel Co. However, the first openhearth steel rail commercially produced was in 1902 at the Tennessee Coal, Iron & Railroad Co.'s plant at Ensley, Ala. — a plant built for the production of basic steel from the high phosphorus ore of that district. During the period from 1902 to as late as 1913, all of the principal rail mills of the United States, which had been rolling bessemer rails, gradually changed to openhearth; first by rolling a few heats per turn and gradually increasing until the production of openhearth rail steel became 100%. Today, all rail steel used on American railways is basic openhearth.

Rail sections were continually increasing and, in 1915, the "ARA-A" and "ARA-B" sections mentioned above were changed to "R.E." sections. Rails for use in railroad mainline tracks increased in weight until, at the present time, the standards for mainline track are the existing 112-lb. and 131-lb. rails of the R.E. sections, standardized by the American railroad industry in 1934.

Coincident with this change in rail sections and increase in weights per yard, the quality of basic openhearth steel for rails improved continuously until, at the present time, the close attention to metallurgical control given in the openhearth, blooming and rail mills, and all finishing departments, has resulted in a steel very superior to that produced earlier. This has been a matter of my direct personal knowledge since 1905, and has been especially noticeable since the inauguration in 1912 of an inspection practice on rail by my company, extending into all departments of manufacture.



Somewhat Incomplete But Nevertheless Representative Figures Show a Continuous Increase in Average Size of Rails Used by American Railroads

The rapid movement of heavy passenger and freight equipment and the need for utmost economy of operation have demanded every precaution and refinement in the production of the raw steel and the mechanical finish of the rails made from it. Safety and wear resistance have been the two important objectives. Mention of several important developments in this work is necessary.

Transverse fissure failures, well known to all readers, have been proven by investigations sponsored by the American Railroad Administration and the Manufacturers' Technical Committee to result from internal shatter cracks. Shatter cracks, in turn, have been eliminated by the controlled cooling process, originated by the Canadian metallurgist I. C. MACKIE, and now in use in the production of rails at every rail mill in America. This process originated in 1931 and was in operation at all United States rail mills early in 1936. It was briefly described in METAL PROGRESS in July 1936.

The detection of transverse fissures in rails in track has developed increased safety. Equipment to detect transverse fissures before rails fail was invented by SPERRY in 1926 and is used either directly, through the American Railway Engineering Association, or by certain roads which have built and own such equipment.

Increase in the useful life of rails has been made by the welding up of the batter at joints. This practice originated about 1920 and now is quite generally used. Also in recent years, commencing in 1932, rails, either in track or in the mills, have been end-hardened to reduce the tendency of rail ends to batter and develop low spots at the joints.

Emphasis at this time should be made to the increased attention and the very generally superior care that is being given by the maintenance and engineering departments of the various railroads to the many important problems of track maintenance.

Through all this period, particularly in recent years and even as far back as 1905, various attempts have been made to heat treat rails with the object of securing superior physical qualities. Very definitely these attempts at heat treating, including many extensive trials, have not resulted in a heat treated rail that fills the service and safety requirements. This is due substantially to the fact that a rail is an irregular section of considerable length (39 ft. is now standard). No practical method has yet been secured for heat treating such sections on a commercial basis and in a manner that will insure the resulting uniformity and wear resistance desired, and the safety that is essential.

Experiments also have been made with various alloy or semi-alloy steels. These have been handled as large scale experimental trials, either with negative results or results that do not justify the extra expense.

What the future holds for rail steel development we do not know, but there is no engineering material that is subjected to as severe service conditions as rail steel, and in which elements of safety, wear resistance and economy must be given primary consideration.

FABRICATION OF STAINLESS STEEL INTO CHEMICAL & PROCESS VESSELS

By Philip L. Coddington
Upper Montclair, N. J.

SOME ten years ago Mr. Jones bought a stainless steel vessel for a definite process in his plant.

It was of 18-8 low carbon plate (0.06% carbon) and of welded construction. It was not heat treated after fabrication. At the time Mr. Jones was told all about "carbide precipitation", was shown examples of material that had been subjected to the Strauss test, and was satisfied that the vessel (made of low carbon metal, as directed) would have a long useful life under his service conditions (in a slightly oxidizing corrosive medium) and give him a better product, free from previous contaminations of iron stain.

Mr. Jones was right. After more than ten years of almost continuous service at temperatures in the neighborhood of 400° F., his foreman certified that the vessel was absolutely as good as new.

He now required increased capacity and decided to duplicate the vessel. He started to arrange to do so, but immediately ran into difficulties. Research had wrought great changes in the factors upon which his previous decision had been based. He was reminded that during its entire life this vessel had harbored zones adjacent to the welds which were sensitive to intergranular corrosion. He learned that 18-8 with carbon as low as 0.02% was subject to intergranular sensitization.

"But," said Mr. Jones, "after ten years of service under my operating conditions there is no evidence of intergranular corrosion in my vessel. However, it certainly won't do any harm to heat treat after fabrication, so let's do that. When may I expect . . . . . ?"

Here he learns that other factors must be brought in line with 1940 conditions before he can get down to a discussion about delivery dates. State Code requirements now call for heavier steel flanges for bolting the cover to the body of the vessel. "O.K.," says Mr. Jones, "that's progress. These Codes promote safety and I'm all for that. Now . . . ."

But he finds that the mass of the flanges will cause the stainless adjacent thereto to be sensitized during heat treatment since they cannot be cooled with sufficient rapidity.

Mr. Jones has been learning a bit himself, however, and he is ready for this one. "We'll use stabilized material," says he, "we'll stress relieve at say 1550° F. with a slow cool and . . . ."

Unfortunately Mr. Jones had not taken into consideration the difference in coefficient of

expansion between the plain steel flanges and the stainless vessel. Temperature stresses of dangerous magnitude might result therefrom, and cause "stress corrosion".

His education on stress corrosion took a considerable time as there appeared to be many conflicting views on the subject. He pursued the subject doggedly, however, and finally called his advisers together and thanked them for the time they had so kindly devoted to the solution of his problem.

"Gentlemen," he said, "we will take up the subject where we left off and we'll dispose of stress corrosion in this manner: It appears to occur in the 18-8 materials under internal or external stress, when certain chlorides are present as corroding media. I don't have any such chlorides in my process. So much for stress corrosion.

"Now I don't question the value of all the research that has been done in the past ten years. It has unquestionably extended the field of usefulness for the stainless alloys. I am convinced that it has made possible the successful use of stainless in many processes where failures might have occurred ten years ago.

"I am sure you will all agree that it is both unscientific and unsafe to draw too sweeping conclusions from particular, restricted cases. I would not do so myself and I would certainly not wish to influence others to do so.

"However, my particular interest is in a very specific case where I have evidence of results obtained. I propose to build my new vessel as nearly duplicating my old one as the Code will permit. My process has been carefully standardized and I'll take my chances on all the sensitization, intergranular corrosion, stress corrosion and other dire results that may occur under other conditions.

"If I don't see you before then, come around ten years from today and I'll let you know how both vessels are doing. Good day, gentlemen."

[Any resemblance of Mr. Jones or his advisers to persons living or dead is entirely metallurgical and probably allotropic.]

While a vessel that has proven satisfactory in a given service may best be duplicated if more capacity is necessary, selection of the proper "stainless" alloy is a matter of prime importance in new processes where the product must not be contaminated with metallic compounds picked up from the container. Good fabrication practices are outlined in some detail, as they are well known only in shops specializing in these high alloys.

Generalities About New Applications of Stainless Steels

If after the above narrative we may proceed to a serious consideration of stainless steels in the process equipment field their record will be found to indicate that Mr. Jones' confidence was neither fictitious nor ill-founded. There are many instances where the alloys of ten and more years ago have served well in equipment under process conditions that have remained constant. There is no reason to believe that they will not continue to serve equally well for many years in the future.

Likewise, continued research has brought about improvements in the alloys themselves and refinements in the technique of their manufacture and fabrication.

Constant vigilance has been required to keep each alloy well within its particular sphere of useful application. This has resulted in a distinctly pardonable conservatism in even the staunchest advocates of the extension of stainless markets, and may have brought about a few cases of "generalizing from particular instances". Developments have, however, been overwhelmingly toward broadening the boundaries of the field of usefulness for this group of alloys along lines which will offer a firm foundation for even greater expansion in the future.

In stainless process equipment the primary requisite has been for control of corrosion and prevention of product contamination during processing. Long life is frequently considered a secondary, but none the less acceptable, consequence of the fulfillment of the primary requirement.

The extension of the field of application for these alloys has necessitated more careful control over the factors of

1. Fabrication technique
2. Design
3. Selection of the alloy
4. Process operation

All of these factors are of course interrelated and any change in one has its resultant effect on the others.

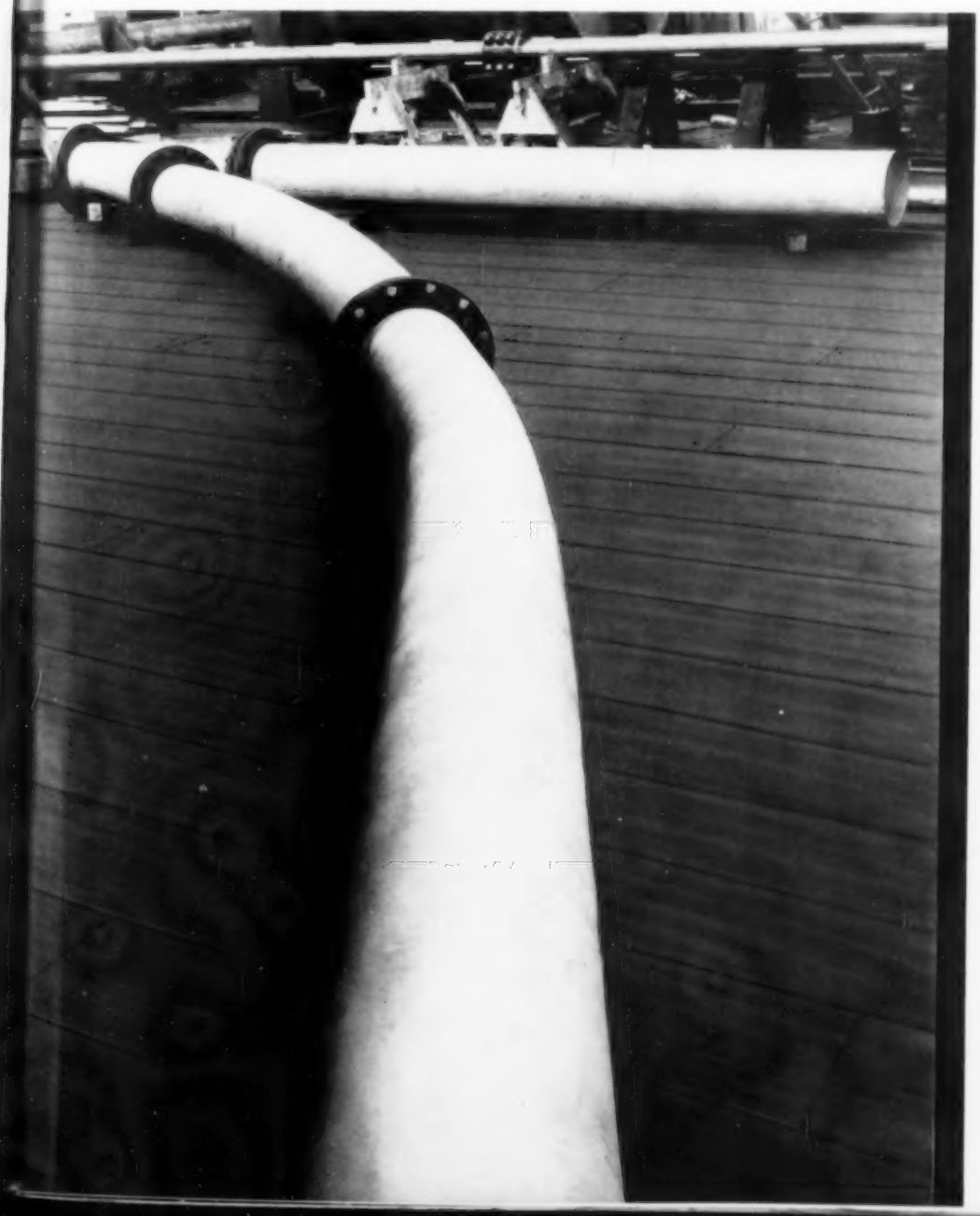
Fabrication Technique

Several of the large chemical companies have developed codes for the guidance of their designers and operating personnel, and detailed specifications for the fabrication of welded equipment made from the stainless alloys. Factors of design, service conditions and operating technique are, in this manner, carefully related to fabrication requirements to insure proper functioning in the given process. Such fabrication specifications generally cover the following:

1. Chemical analysis of materials.
2. Physical properties.
3. Routine required for approval of welding operators.
4. Heat treatment of mill material.
5. Heat treatment of fabricated equipment (where required).
6. Requirements for composition of deposited weld metal.
7. Preparation of plates for welding.
8. Welding procedure.
9. Dimensional tolerances, finished vessels.
10. Cleaning of finished vessels.
11. Inspections.
12. Tests.

Principal emphasis here, as in the codes and various specifications for steel pressure vessels, is on welding technique to insure sound, strong structures. However, many shop practices that are good in mild steel fabrication may be extremely bad in stainless. Supplementary instructions to the fabricator are frequently given to suit the requirements of the individual job, and experienced inspectors are frequently sent into the shop to give their advice on any questionable point.

Hot Sulphite Liquors in Paper Mills Are Not "Violently Corrosive", Nevertheless Austenitic Stainless Steels Need Considerable Molybdenum in Them for Satisfactory Service. Metal in this pipe also contains columbium to enhance weldability



Of course the experience of the fabricator is of vital importance. It is essential that his men have a knowledge of the character of the alloys on which they are working and of the way they react to routine shop operations. Inadvertent lapses from good practice may cause damage which is not readily detectable by any non-destructive tests, but is responsible for subsequent grief.

A few of the essentials for good practice will bear reviewing at this time, even though they are well known to those fabricators and engineers experienced in this field.

Since stainless is employed primarily to resist corrosion and prevent contamination of product, it is important that the stainless itself be not contaminated. Therefore it should be fabricated in a clean shop. Plates and shapes on a dirty floor, walked upon and catching soot and dust, are subjected to unnecessary

hazards of serious contamination. It is doubly important that material be clean when heated, as for welding, forming or bending. A smear of oil left on the surface may cause sufficient pickup of impurities to render the equipment unfit for many process applications.

The source of heat for bending and forming operations is likewise important. Coke fires, traditionally used in boiler shops, are unsuitable; from them carbon and sulphur may be absorbed to cause brittleness, cracking and loss of corrosion resistance. Furthermore, the heating medium should never be of a highly reducing nature, but preferably on the oxidizing side.

It is well known that such heating changes the structure of the austenitic chromium-nickel alloys. To restore their true austenitic characteristics, with all carbides in solution, a subsequent quenching from 1900 to 2000° F. is required for the alloys not stabilized with titanium or columbium.

Where surfaces have acquired scale from heat, it is necessary that they be thoroughly cleaned. (All the stainless steels resist scaling under heat, but the relatively light scale which does form is extremely adherent.) Sand blasting is sometimes permitted; objections are based on the tendency of the blast to drive scale and impurities *into* the surface. It also produces a rougher surface than is frequently desirable.

Scale can best be removed in a good clean pickling solution. (For 18-8 use 20% HNO_3, 3% HF, 77% H_2O at 150° F. under good ventilation.) Supplementary brushing and scouring is effective for loosening the scale and reduces the chance of over-pickling and undue loss of thickness. Cleanliness is important; a dirty solution can cause serious damage to stainless steel surfaces.

For wire brushing use brushes made of stainless steel. An ordinary steel wire brush will leave particles of iron on the surface which will start rust spots and defeat the purpose of any cleaning up operation.

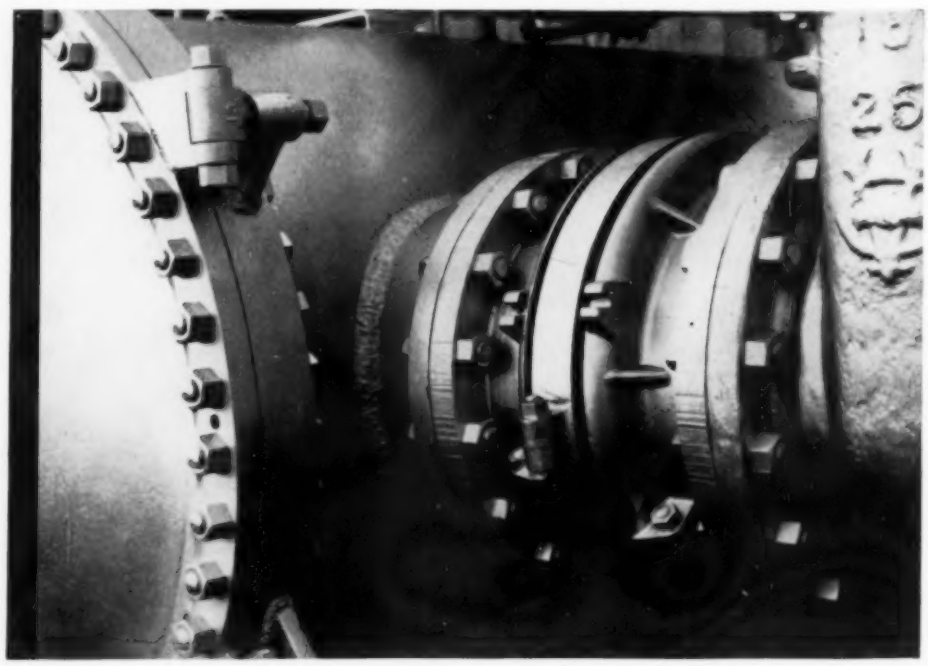
The stipulation that all slag be removed from welds should be scrupulously carried out. Small particles of adherent slag can cause most undesirable reactions in heating operations or under service conditions.

One of the most tedious fabricating operations is cutting the openings in shell and heads for nozzle connections. These openings are usually made by a series of punched or drilled holes after which edges are laboriously chipped and ground smooth.

The carbon arc will cut such openings rather acceptably, so far as appearance is concerned, but carbon is naturally picked up by the adjacent metal. All this should be carefully chipped away. Unfortunately, there is no sure method of readily determining the depth of such carburization. Therefore carbon arc cutting of austenitic alloys has not been generally accepted as good practice.

Severe cold working, particularly of the austenitic stainless steels, should be avoided, and good design will rarely require it. When shapes required are so intricate as to demand severe cold work, a stabilized material is generally specified in order that internal stresses may be relieved without carbide precipitation. Stress relief is normally done at temperatures of 1350 to 1550° F. followed by slow cooling.

Good fabrication practice calls for "passi-



Expansion Joint Between Oil Refinery Vessel and Valve. Expansible unit is a stainless steel liner with accordion bend, reinforced outside by loose ring. The number of folds in the liner depend on the anticipated movement

vation" of a completed process vessel in warm 20% nitric acid, followed by washing with plenty of clear water.

These requirements are all essential to satisfactory fabrication. There are frequently other special requirements for special conditions of service or specific types of equipment. To the rough-and-ready boiler maker this may seem like "babying the stuff", but the boiler maker who insists on being rough-and-ready is hardly qualified to deal with a chemical and metallurgical world where superior products are the result of meticulous control.

Design

A knowledge of alloy characteristics and fabrication technique is essential to the present day designer of stainless steel process equipment. He must likewise be informed on mill practices and the forms in which the various alloys are obtainable. With this, plus an intimate acquaintance with the details of the process for which the equipment is intended, he is well equipped for his work. A large order! Of course an individual with this combination of knowledge would be a rare find indeed. It is essential, however, that the designer have contact with individuals who can supply the required items of specialized information.

Selection of the alloy may be a simple matter for the chemical engineer, as his knowledge of the corrosive conditions, temperatures, pressures and other details of the process may indicate immediately the use of an alloy that he knows from experience will serve satisfactorily. If not, the chemist will have conducted tests to determine the alloy most suitable for the actual conditions. These tests will have been conducted on welded, heat treated and unwelded samples, in stressed and unstressed conditions, and should be planned to give a clear indication of temperature and concentration limits within which the selected material may be expected to serve.

The designer may now give consideration to the forms in which the selected alloy can be obtained. Possibly it is not rolled in shapes such as angles, tees, and other irregular sections. Shall these be formed by bending plate, or built up by welding together bars of the proper dimensions? Formed angles will have rounded edges and if the construction requires that they be welded to relatively thin material, the fabrication will be difficult; the necessary heavy weld will risk burning through the thin material.

The detailed nature of the required equipment will have been considered with particular regard to the likelihood of locked up stresses in any of the finished parts. While it has so far only been established that certain chlorides cause rapid stress corrosion, it is obviously good practice to eliminate severe stresses in all parts in contact with liquids whether structurally important or not.

Thus the selection of the alloy will be influenced by the nature of the fabrication. If severe stresses are likely the austenitic steels should be of the stabilized type, the reason being, as previously stated, so that stresses can be relieved by heating and slow cooling through a temperature range which would precipitate carbides in an unstabilized material.

In the top construction of process vessels attention should be given to self cleaning features. Top-head and outlet necks should be designed with drip lips to clear them of liquids and avoid accumulation of dried solids on surfaces. Clean surfaces will extend the life of the vessel and lessen opportunities for unwanted reactions in the process.

Welds should be located where they can be readily made in a downward or horizontal position. Corner welds should be avoided; it is poor economy to omit a flanging operation where it will eliminate a corner weld. Welds should be smooth and rounded where reinforcement is left on, to prevent lodgment of sludge or solids during the operation.

As to calculations for strength: The regular codes have not as yet been modified to cover the specific characteristics of the stainless alloys. (Weld efficiencies are calculated the same as in steel design.) The situation is therefore somewhat confusing to the designer. Good practice must for the present follow the conservative requirements in the codes for steel pressure vessels, although provision for additional thickness to take care of corrosion is naturally seldom needed.

Vessels in Operation

Limits of operating tolerances of temperatures, concentrations and composition of product are definitely established for the process. Since these limiting factors have been determined by the chemist for the constructional material selected, controls must be accurately

maintained. A few instances will be given:

A vessel with a coil may usually be operated within the limits specified, but in batch operation the top section of the coil may be out of the liquid in the late stages of the run. Temperatures in this dry section of the coil can readily exceed the limit set, and then trouble is likely. Either the design should be changed so the heat may be shut off coil sections when dry, or operations so controlled that the entire coil surface is always immersed.

Changes in practice which appear of minor importance should be carefully checked before they are approved.

In a recent instance a very minor ingredient was added to the feed. Fortunately prompt warning was given by the rapid disintegration of a screen (highly stressed) at the entrance. In this instance the addition contained a chloride which destroyed the highly stressed material before any serious attack had started on the main body of this expensive equipment. Stainless is not normally recommended for resistance to chlorides, but here a minor change had been made in the process without consideration of possible major consequences.

Such instances are becoming increasingly rare. In fact, greater refinements in process control are working to the increasing advantage of these remarkable alloys in broadening their field of usefulness. In general a stainless alloy is selected for a given piece of equipment because of its tested resistance to contacts that would be "poison" to other materials. Its relative immunity to this "poison" will continue so long as its physical and chemical characteristics are kept within limits determined by test, and the characteristics of the "poison" are not changed. Such limits are normally made broad enough to allow a reasonable margin of error.

Trends

New processes in chemical industries follow each other with amazing rapidity. More than once in recent years a process has become obsolete while equipment was being completed and before it had seen actual service.

This has led several of the larger users to draw specifications for equipment with an eye to more general serviceability. Such considerations have had a very important influence on selection of the alloy and its design and fabrication technique.

In contrast to this trend toward standardization for diversified use, certain new chemical processes have required highly specialized alloys with properties which limit them to very definite applications. In such cases slight extension of limits as to temperature or concentration may mean the difference between success and failure with the ultimate product. To attain the desired ends an alloy with almost insufferable manufacturing and fabricating characteristics may have been evolved. Considerable research is now being devoted to these "queer" alloys with the object of modifying their "queerness" without eliminating their useful properties. Thus their fields of application may be widely extended.

Another interesting trend is this: The increased importance of stainless fabrication is showing its effect on the type of shop where it is fabricated.

Steel equipment fabrication quite readily divided itself between the sheet metal shop and the plate or boiler shop. Most stainless process equipment requires a range of thickness between 16-gage sheet and ½-in. plate, with many combinations and much overlapping. The trend here is not clearly defined as yet, as there have been many compromises between sheet metal and plate shop practices. However, a versatile personnel has been developed whose skills refer directly to the stainless materials, and tools and practices will be evolved to meet their special requirements.

One last instance: Not long ago one of the earlier stainless alloys was rediscovered by the researchers into a new chemical process. This alloy had fallen into general disuse because of difficulties in its manufacture and fabrication. It was thought that later alloy types had satisfactorily replaced it, covering all its useful fields of application. The researchers, however, found no other material that would give them characteristics which afforded the essential slight extension of the limits on their process. This slight extension actually represented the difference between commercial success or failure of the process. In consequence, a very respectable tonnage of this resurrected alloy has been made and fabricated.

This last instance may not indicate a trend, but with so many considerations to take us far afield in the ever-broadening use of the stainless alloys, perhaps it points toward the advisability of our looking in on Mr. Jones occasionally just to see whether or not we're keeping up with him.

SORBY'S PIONEERING WORK ON THE MICROSTRUCTURE OF ROCKS AND METALS

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THE SHORT ARTICLE in last July's issue of METAL PROGRESS concerning "Metallography's Diamond Jubilee" — incidentally, on this side of the Atlantic the 60th anniversary is regarded as the diamond jubilee, not the 75th — justly draws attention to the debt which metallography owes to Dr. H. C. SORBY, whose pioneer work in the sixties on the microstructure of iron and steel attracted so little attention at the time but was subsequently the foundation on which the present superstructure of modern metallographic examination has been built. You comment on being unable to discover any record, except a ten-line abstract, of the paper which he gave to the British Association in 1861, and which contained the first pictures of the microstructure of steel ever published. Unfortunately, there does not appear to be a copy of this paper in existence; the present writer recently examined the bound volumes of SORBY's scientific papers and notes concerning them which have been deposited in the library at Sheffield University but could find no copy of it.

Perhaps, however, the following notes regarding SORBY's early work and the methods he used so successfully (not only with metals but also with rocks, his study of which preceded that of metals) may be of some interest to readers of METAL PROGRESS. Most of the information has been culled from the first and second Sorby Lectures given respectively in 1914 and 1921, by Prof. W. G. FEARNSIDES and Prof. C. H. DESCH to the Sheffield Society of Engineers and Metallurgists. The title of Professor FEARNSIDES' lecture was "On some Structural Analogies between Igneous Rocks and Metals", a subject which enabled him not only to describe SORBY's work in applying the microscope to the study of rocks but also to trace its subsequent extension to the examination of metals. Doctor DESCH took as his text "The Services of Henry Clifton Sorby to Metallurgy" and while he devoted his attention mainly to the metallurgical side, he also drew analogies between this particular work and the many other scientific interests which had attracted SORBY. The present writer would thank these gentlemen for readily placing at his disposal the information contained in these lectures.

The idea of preparing sections of rocks so thin that they could be examined as transparencies under the microscope appears to have come to SORBY as a result of a chance contact with a surgeon named WILLIAMSON who, SORBY found, was cementing flat pieces of wood, teeth,

"High Magnification" Used to Mean 650 Diameters; Today It Means 3000 or 4000 in Metallurgical Microscopes Fitted With Every Convenience. Courtesy Jones & Laughlin Steel Corp.'s Research and Development Laboratory

scales, bones and other hard objects onto glass and rubbing them down to a thinness which allowed them to be treated as transparencies. SORBY liked the method, saw at once its possibilities, learned it and proceeded to make similar sections. He then applied it to rocks and, in 1849, prepared the first rock slice ever made. He developed a technique for the preparation of such slices which is essentially that used at present. As Professor FEARNSIDES has stated, SORBY's paper "On the Microscopical Structure of the Calcareous Grit of the Yorkshire Coast", which was published in the *Quarterly Journal* of the Geological Society, January 1851, contains intrinsic evidence that by that time he was a master of this technique and was familiar with the use of the polariscope and almost all the arts of petrographic analysis which, in 1914, it was found practicable to teach degree students at the university.

Applying his methods to the study of other British rocks, SORBY found that those of older formation were often altered by the effects of pressure; turning aside to investigate this, he developed (1856) the now accepted theory of the origin of slaty cleavage and of the formation of mica schist.

Igneous rocks next claimed his attention and the paper which he gave to the Geological Society in December 1857, and which was published in 1858, records his work in distinguishing between aqueous and igneous origins of rocks. The full title of this early paper (which remains the classic on the subject of "fluid cavities" and is still an authority consulted by workers of the present day) was "On Some Peculiarities in the Microscopical Structure of Crystals Applicable to the Determination of the Aqueous or Igneous Origin of Minerals and Rocks", the peculiarities described being minute inclusions imprisoned in crystals. Making the assumption that materials once completely surrounded by a crystal are hermetically sealed until the crystal is destroyed, SORBY interpreted the inclusions as surviving samples of the mother liquor from which the crystals grew. In his laboratory he watched the growth of artificial crystals under various conditions of temperature and pressure, from solution in water, from sublimation, and from igneous fusion, and he explained the peculiarities of natural crystals by analogy and by their similarity to the crystals which he had made. Rocks of many types came under his observation and the approximate temperature and pressure of the formation of each were deduced from the characters of the microscopic inclusions which their crystals contained.

That the "relative size of the vacuities in fluid cavities" could thus afford such important evidence of the origin of rocks was beyond the comprehension of many of the foremost geologists of 1858 who received the paper with ridicule. SORBY nevertheless worked on, giving his attention to particular physical problems which had been raised by his work on crystals. In one instance, he melted a mass of several tons of syenite, a crystalline granite, and then allowed it to cool slowly in order to obtain evidence as to crystal structure. He sought for inclusions in other sorts of rock and found them in the stony constituents of meteorites and from this an obvious step took him to the examination of metals. As he has stated, "It was a natural thing that I should be led from the study of the microscopical structure of rocks to that of meteorites, and in order to explain the structure of meteoric iron I commenced the study of artificial irons."

Work on Metals Starts

Sorby began his work on metals in 1863, and employed two experimental methods. One was that of "nature printing" which had been used at an earlier date by some students of meteorites, and consisted in etching deeply the polished surface of a specimen of suitable thickness so that a pattern in relief was obtained. The etched specimen was then placed in a printing press and inked and could then be printed from in the same way as an illustration by wood engraving. The method is very well adapted to show fairly coarse and clearly marked structures and it was perhaps fortunate that Sorby had at hand a commercial form of steel — cemented bar or blister steel — which had these characteristics. This method, which was the subject of Sorby's earliest metallurgical paper, given to the Sheffield Literary and Philosophical Society in February 1864, was afterwards neglected in favor of photographic methods for reproducing metallic structures, but in recent years has again come into use in the form of macro-etching for revealing ingot structures and flow lines in forged or rolled material.

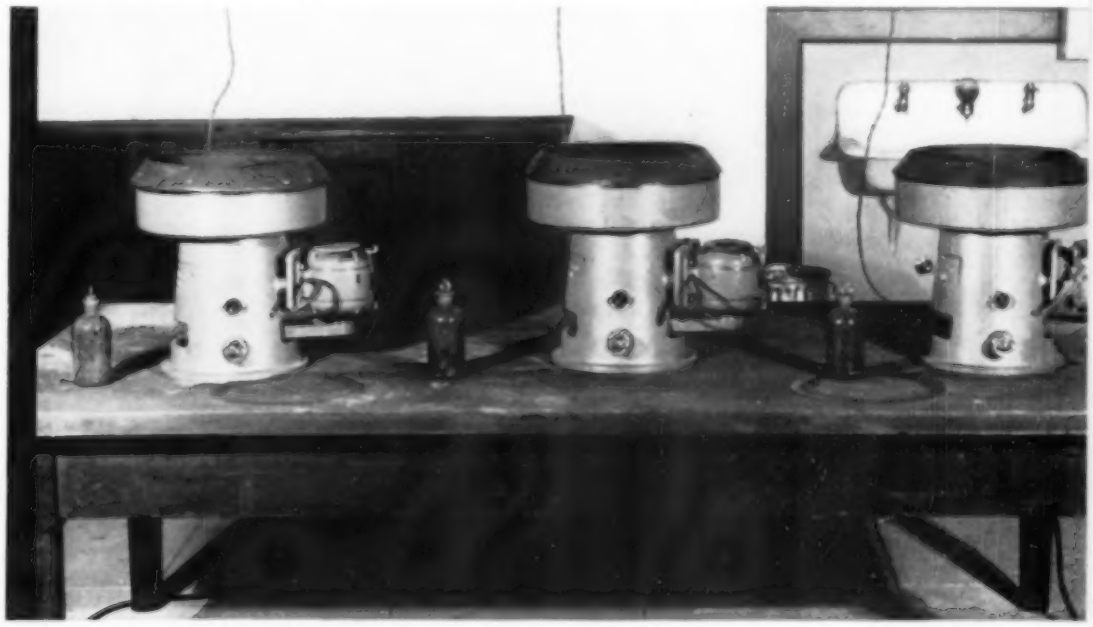
The second method was the one which has been generally adopted and consisted in polishing and lightly etching a small specimen, examining it by means of the microscope and recording, if necessary, its structure by drawing or photography.

According to the late Professor Arnold, Sorby's method of preparing specimens was as follows; one can see its similarity to that which he had developed so successfully for the preparation of rock slices: Pieces about 1¼ in. square and 0.10 in. or less in thickness were used, and after filing smooth were cemented with hard Canada balsam to a plate of glass. The surface of the specimen was then ground down on a glass plate using powdered rotten stone, with water, as an abrasive. This was followed by polishing with the finest rouge on wash leather. The polished specimen was then etched with 1% nitric acid, well washed with distilled water, dried with absolute alcohol and mounted like a rock section with Canada balsam under a cover glass.

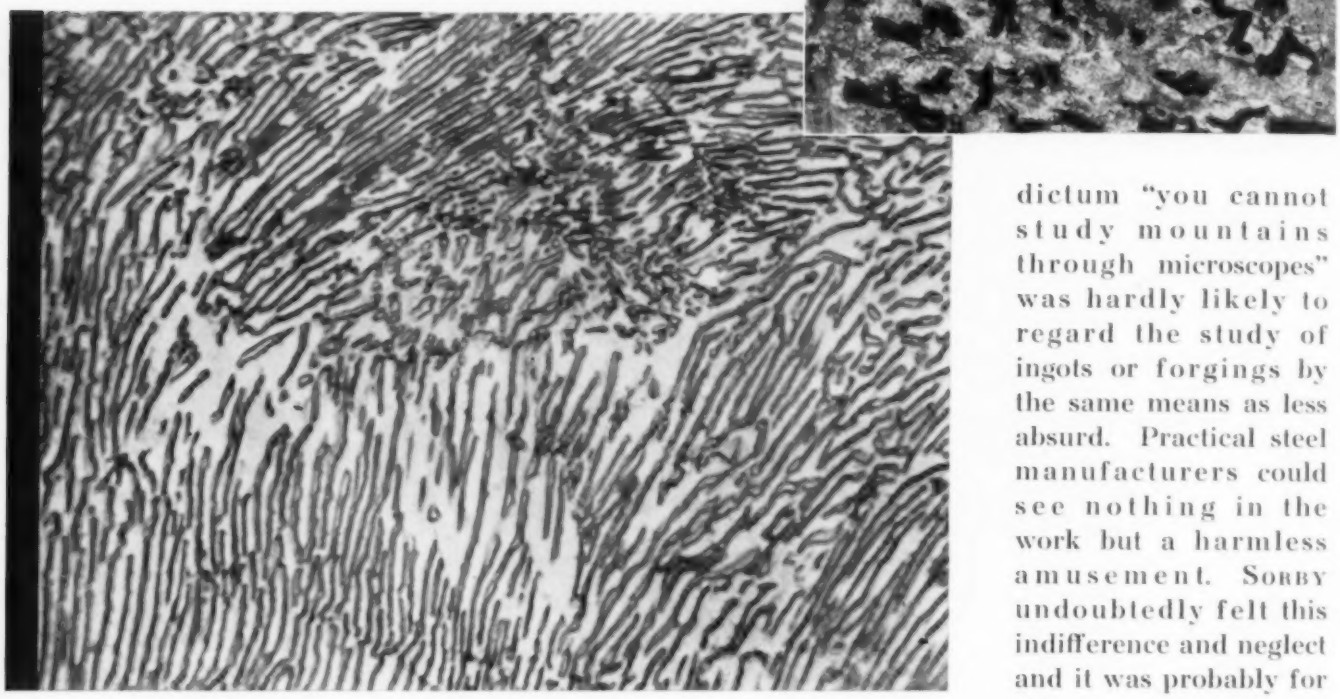
Specimens mounted by Sorby in this way were preserved in the Department of Metallurgy at the University of Sheffield and at the time when Dr. Desch — then Professor of Metallurgy — gave his Sorby lecture in 1921, the present writer had the privilege of examining closely a number of them. The protective coating had served so efficiently with some of these specimens that their structures could still be clearly seen — after the lapse of 50 years — through the protective cover glass; a sample of wrought iron was successfully photographed without removing the cover glass. In other instances the film of Canada balsam between the surface of the specimen and the cover glass had become partly opaque, yet when this film was removed by a suitable solvent, the original etching was found to be as brilliant as when the sample was first prepared. A number of these specimens were also photographed.

This method of preparation was necessarily slow as no mechanical appliances were used, all grinding being performed by hand. One of Sorby's sections familiar to a past generation of students in the Sheffield metallurgical school — including the writer — and known to a wider circle of steel works chemists through being the subject of the frontispiece in Brearley and Ibbotson's well known classic "The Analysis of

It Took Sorby's Assistant Five Weeks to Hand-Polish a Specimen of Spiegeleisen. It could be done in less than an hour on this battery of variable-speed polishing disks



Steel Works Materials", consisted of spiegeleisen and, due presumably to brittleness, the 1¼-in. square slice had broken during preparation into three dozen or so separate fragments each of which had been mounted separately in its proper place. It was stated by Professor Arnold that this specimen was ground by a laborer who was paid £1. per week for his services and



High Magnification Reveals a New Order of Structure in Cast Iron, as Dr. Sorby Found in Steel. The larger micrograph at 2500 diameters reveals a laminated structure hardly suspected in the cloudy gray matrix viewed at 50 diameters. Courtesy General Motors Research Laboratories

that his bill for this single specimen amounted to £5.

In his later work Sorby used emery papers placed on sheet glass, still grinding entirely by hand, but found that the scratched surfaces produced by the emery were unfit for polishing. He overcame this, as he describes in his paper in 1887 to the Iron and Steel Institute, by rubbing these surfaces on the finest "Water-of-Ayr" stone, thus removing the scratches and also, as he points out, the distorted structure underneath. He also used wet cloth treated with crocus powder or with rouge for polishing and, incidentally, obtained a sort of "polish attack" by rubbing dry with rouge on a sheet of parchment laid over a plate of glass.

His early papers, however, attracted very little interest. A generation of scientists which had ridiculed his work on petrography with the dictum "you cannot study mountains through microscopes" was hardly likely to regard the study of ingots or forgings by the same means as less absurd. Practical steel manufacturers could see nothing in the work but a harmless amusement. Sorby undoubtedly felt this indifference and neglect and it was probably for this reason that he soon afterwards turned aside from the study of metals to other subjects which claimed his attention, and only returned to it many years later when other investigators, to whom his work was apparently quite unknown, experimented in a similar way. Martens published his first paper in 1878, and Wedding followed with another shortly afterwards. As Dr. Desch has pointed out, these experimenters, though later in date, were inferior to Sorby in manipulative skill and also far more faulty in their interpretation of the structures they observed. Wedding gave a paper to the Iron and Steel Institute in 1885, and an inspection of the drawings which accompanied it makes it clear that his preparation of the surfaces must have been imperfect, as some of his illustrations can have had little resemblance to the actual structures of the specimens they were supposed to represent. Sorby also contributed a paper to this meeting — a paper obviously well illustrated if one may judge by comments passed during the discussion of Wedding's paper — but for some unknown reason it was not printed in the published volume of the *(Continued on page 86)*

OPERATIONS ON THE PIT SIDE OF A MODERN OPENHEARTH

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TRENDS of modern practice in the construction of the openhearth furnace and its auxiliaries were described in an article in the January issue of METAL PROGRESS. Let us assume that a heat of steel has been properly made in one of these units and is ready for tapping. We will now endeavor to follow the operations through to the production of first class ingots.

The oxygen lance for "burning out" tap holes has proved to be a great labor saving device. It is merely a long piece of small pipe carrying a stream of oxygen gas at moderate pressure. Tapping was formerly done by brawn and muscle using a long bar and sledge hammer. If there was an extremely hard tap, it was often necessary to actually melt out the tap hole by creating a boil in the bath of finished steel, and sometimes required 24 hr. before the metal was finally drained from the furnace. (Oxygen is also very effective on the pouring platform for keeping the ladle nozzles open when handling "cold" heats.)

Even the modern method has been improved upon by the installation of an oxygen distribution system known as the "Driox system", essentially a central station where a supply of liquid oxygen is stored and an evaporator for furnishing oxygen which is then piped to points of use. Numerous convenient outlets are provided at the furnaces, and many serious accidents which resulted from explosions in oxygen hose and near the connections have been eliminated by such a distribution system.

Ladle and Teeming Practice is known to have an important relationship to yield and quality of the product. This has focused considerable attention on this phase of openhearth operation. Despite all precautions and attention to insure satisfactory furnace practice, yield and quality are vitally affected by conditions arising in the pit section which are entirely beyond the control of the furnace personnel.

Bad steel cannot be perfected by manipulation during teeming, but through the proper handling of "off heats" serious losses, which in many cases arise, can be greatly minimized. Conversely, good steel can be ruined as a result of poor workmanship in the pit and rendered unsuitable for orders where exacting surface and physical requirements are essential.

Many defects which develop in the semi-finished product, or carry through to the inspection table, have their origin in ladle and teeming practice. Sufficient evidence on this point has been secured to warrant careful investigation

of pit operations when an abnormal amount of such defects occurs at final inspection.

Running stoppers probably head the list of causes for defective product traceable to the pit; furthermore, loss of steel and safety are involved in nearly every occurrence. A survey of a number of plants shows considerable variation with respect to the frequency of running stoppers. Some experience very little difficulty, while in others it constitutes a major problem. Other features of ladle practice have considerable bearing on quality results as a whole, pouring technique and mold conditions also being of major importance.

Ladle design has been given considerable attention as the capacity of openhearth furnaces has increased. Many existing furnaces have been rebuilt for tapping larger heats and certain limitations with respect to size, weight, and design of ladles had to be overcome. Oval ladles have been a solution where increased depth would be detrimental to quality, or where overhead clearances on crane hoist would be a limiting factor in placing the ladle over the molds. Construction of oval ladles of larger capacity has also made it possible to provide proper clearance beneath the furnace runner, where depth of support foundations is a limiting factor. The width at the trunnions is unchanged; the oval type is thus readily adapted to existing ladle stands and bales.

Welded ladles have saved considerable weight, and enabled some to increase the size of heats even when building columns, crane runways and ladle cranes were of insufficient capacity to carry larger loads. The welded ladle is approximately 15% lighter than other types of the same capacity, and this means 7 to 8 tons on a ladle having a capacity of 125.

Stopper Rods and Nozzles — Proper assembly of the brick protecting the stopper rod, and securing the head to the rod, are both important details of ladle practice. The joints of the sleeve brick should not be forced together too tightly; this might break the graphite stopper head when expansion takes place. On the other hand, if sleeves are fitted too loosely, steel or slag will penetrate the joints and the rod will be lost. The stopper head may be either keyed to the rod or threaded and screwed in place.

A drying oven is necessary for thoroughly drying the assembled rod before placing it in the ladle. The vertical type of oven is very satisfactory; it is designed for placing the "green" rods in one end and removing the dry ones from the other. Such a furnace should be equipped with a recording pyrometer. A definite drying cycle is to be followed.

Rate of pouring has been the subject of considerable discussion among steel makers. The use of single versus double nozzles has been argued pro and con. Where a large number of ingots are poured, necessitating frequent shut-offs, the double nozzle system has overcome much of the difficulty arising from holding the metal too long in the ladle. While the double nozzle does not reduce the pouring time to exactly one-half that required with the single nozzle, nevertheless the speed-up is considerable. In pouring a heat of 28 18x39-in. ingots with a single 2-in nozzle, 24.53 min. were required, whereas it required 19.22 min. with two nozzles.

Oval shaped nozzles have come into more general use for their special advantages in pouring slab-shaped ingots. By their use the tendency for the metal to strike the mold wall on the narrow dimensions has been greatly minimized. Length of nozzle is also a factor. The tendency has been toward longer nozzles; a number of plants are using nozzles 12 in. long or longer. The longer nozzle prevents spraying of the metal stream to a considerable extent.

Ingot Mold Practice

Mold practice has considerable bearing on the life and service of the mold together with the surface qualities of the ingot. Larger ingots have increased these problems to no small extent, and this is particularly true of the slab type where the large flat area is very susceptible to fire cracks and gouges.

Greater importance is being attached to the cleaning of molds and its effect on quality of steel and life of the mold. Inclusions, surface defects and "stickers" result from poorly cleaned molds. A more or less haphazard job usually results where the yard gangs are required to stand on top the molds to clean them. The amount of cleaning in this case is dependent upon the temperature of the drag. This condition is further complicated by a serious safety hazard. A more effective job of cleaning is done when molds are placed on the ground; however, where limitations of equipment would necessitate too much delay, a satisfactory job can be done by overhead cleaning.

A movable platform operating over the train of molds provides a safe location for the

cleaners. Fewer men are required because of less fatigue from the heat, and safety hazards are practically eliminated. Slag, oxides and other foreign material are carefully scraped from the mold surface after which the mold is hoisted, the stool scraped and blown off with compressed air.

Various mold coatings are now used, with graphite or tar predominating. Graphite is applied with a spray and the inside surface brushed to prevent dripping down the side, thus forming an uneven coating. Molds are coated with tar, either by spraying the inside surface or dipping the entire mold into a tar bath. A salt solution is also used in some plants.

Points on Good Furnace Practices

No attempt will be made to describe the manufacture of steel, but as an introduction to some remarks on good practices, the following reminders may be useful. Raw materials — consisting essentially of limestone, pig iron and scrap — are charged into the furnace and melted by the direct impingement of the flame and radiated heat from the side walls and roof. The limestone is charged on the bottom; as the metallic charge melts, the stone floats to the surface and forms the base of the slag which absorbs the products resulting from the oxidation of silicon, sulphur, phosphorus and manganese in the charge. The carbon from the limestone and the pig iron escapes as a gas. Burned lime may be used instead of limestone, in which case the melting time is usually shortened.

During the early stages of melting, when the lime rises to the surface, the slag is "heavy" and viscous. Fluorspar is then added in judicious amounts to hasten the melting of the lime and bring about the necessary degree of fluidity.

Iron ore is added to the molten bath in suitable quantities (40 to 50 lb. per ton of product), its principal function being to oxidize the carbon and manganese. Additions of ore are made in limited amounts periodically during the working of the heat. Iron ore additions are stopped when the carbon content of the bath is somewhat above the desired tapping point. Wooden poles or steel rods are then stirred through the bath to agitate the slag and metal, which action lowers the carbon content to the tapping specifications. Iron ore should not be added within one hour prior to tapping.

Manganese in the charge is oxidized to a point where the residual content, in most cases, is below the final specifications and ferromanganese additions are made either in the furnace or the ladle.

The basic openhearth process results in a melt relatively overcharged with oxygen, together with other gases. The steel must therefore be treated with suitable deoxidizers and degasifiers in the furnace or ladle. Aluminum or silicon are the most common deoxidizers and their particular use depends upon the chemical specifications of the product and its intended use. No one deoxidizer will completely degasify the metal, as the chemical affinity of the metals varies for different gases.

Natural laws governing the solidification of liquid metal prevent the formation of absolutely homogeneous ingots and tend to create imperfections which may or may not cause defects in the intermediate or finished stages of manufacture. These imperfections cannot be altogether eliminated, but it is very important that their condition, size, and location be properly controlled.

Basic openhearth steels may be divided into two general classifications: *(a)* Rimming steels and *(b)* killed steels. These terms are descriptive of the behavior and appearance of the metal immediately after teeming in the molds.

Rimming Steel — The common ingot defects in rimming steel are blow holes, scabs and inclusions which later give rise to seams, slivers, blisters and laminated product.

Surface blow holes (or "skin holes" as they are sometimes called) cause the most harm to the product. All rimmed steel ingots have a zone of these blow holes across the bottom, extending up all sides, underneath a sound primary skin varying in thickness. These sub-

It is pointed out that the training of men, so they know the effect, good and bad, of the careful and careless performance of even minor duties about a furnace, will pay many dividends to an openhearth shop making quality steel. Men should not only know what to do, and why, but also be provided with safe means to do it.

surface blow holes materially affect the quality of sheet products, especially when the thickness of the primary skin is less than $\frac{3}{8}$ in. Ingots which have a primary skin approximately $\frac{3}{8}$ in. or more thick, and in which the blow holes do not extend up the sides more than one-quarter the way to the top, are usually satisfactory for most purposes. An ingot with a "thin skin" is likely to produce seams or other defects in the bar or sheet. The size and number of blow-holes and the primary skin thickness are measures of the degree of control over the various factors in the steel making process.

The gases that are usually believed to form the greater percentage of blow holes in rimmed steel ingots are hydrogen, nitrogen and carbon monoxide, the latter predominating. Oxygen is an ever-present gas in the openhearth process, combining readily with iron to form iron oxide, a non-gaseous product. Reactions which start immediately after teeming in the molds liberate considerable quantities of carbon monoxide gas, and as the metal is cooled, this and other gases are evolved and rise to the surface of the ingot. Reaction between carbon and iron oxide evolves carbon monoxide gas, which is believed to be the principal agent producing the effervescing and rimming action in the molds. Much scientific work on this problem was reviewed by JOHN CHIPMAN in METAL PROGRESS for February 1939.

The escaping gases accumulate into bubbles and as the solidification point of the metal is approached, an appreciable amount is entrapped in the semi-liquid or partially solidified metal. The bubbles do not form perfectly rounded blow holes at the surface but rather tend to elongate with their longer axis perpendicular to the cooling surface, that is to say, to mold wall and stool. Both the interior or center blow holes, as well as those located several inches from the ingot surface, tend to a more spherical form.

Action of the metal in the molds is generally used as a criterion of the quality of rimming steel. For instance, the "riser" type of ingot usually indicates over-deoxidation, or a tapping temperature too high. Such ingots are usually of the "thin skin" variety. Over-deoxidation must therefore be carefully avoided. To prevent such riser heats it is the usual practice to slightly under-deoxidize in the ladle and complete the treatment in the molds. Large additions of aluminum to the ingot are not advocated; best results are obtained where the ladle addition is sufficient to deoxidize the metal to the point where only a limited amount is required during teeming.

Killed Steels are usually treated with ferrosilicon in the furnace or ladle and, when teemed, are devoid of action in the molds. The metal is practically deoxidized, and any gases are highly dispersed or in a state of solid solution after the metal has solidified.

This type of steel "pipes" to a greater or less degree, and is usually poured into molds having a hot top, a refractory lined steel box which serves as an insulation, thus lessening the rate of solidification in this region. The hot top holds about 15% of the total weight of the ingot. As the ingot solidifies, the pipe begins to form in the upper portion of the ingot beneath the "hot top"; it is caused by the shrinkage of the cooling metal, and simultaneously molten metal is fed from the hot top into the slowly forming cavity, thus filling the void. In a well designed ingot mold the piped volume is thus confined to the

Welded Ladles Save 15% in Dead Weight, Thus Frequently Permitting the Openhearth to Be Enlarged and Still Not Overstrain Cranes, Runways and Bales

extreme top portion of the ingot. Normal cropping in the blooming mill operations includes the hot top section and leaves a high percentage of material from the ingot proper free of pipe. Hot top practice is usually confined to high carbon steels, forging grades, and alloy steels.

Metallurgical Control

The rapid increase in the production of sheet steel through the expansion of continuous hot and cold strip mills has brought about many new applications for the product. These are so diverse that they cover a wide range of metallurgical and physical requirements.

Factors affecting the surface of an ingot and its interior formation have been subject to considerable study. Despite the fund of knowledge available, there is much still to be learned about the control with greater precision of factors affecting the basic defects.

Exhaustive tests have proven conclusively the close margin between the teeming temperature of steels giving satisfactory results and those of more or less mediocre quality. The optical pyrometer on the backstanding or pouring platform serves a very good purpose, but its indications are subject to large corrections (for emissivity factor) and to experienced interpretation rather than for direct control of the furnacing operations.

Notwithstanding the improved types of instruments available for combustion and temperature control, there still remains a considerable gap in our knowledge of openhearth control, particularly with respect to temperatures of the molten bath. The lack of protective materials for the temperature measuring devices, which can more effectively withstand the erosion of molten metal and slag, still presents an obstacle to much needed progress along this line.

The importance of openhearth practice and its effect on the performance of the product has emphasized the need for more adequate metallurgical data wherein the metal from individual heats can be readily identified in the customer's plant. Probably one of the most important duties of the metallurgist is to keep the steel works currently informed as to the effect of openhearth variables on ultimate performance of the product. Heretofore the "quality" was usually determined by physical inspection and tests at some intermediate stage of manufacture, notwithstanding the fact that workability of the finished sheet in the press shop and its performance in the field are the most important considerations.

Personnel—Technical literature has mainly dealt with the personal equation in a more or less abstract manner. However, the human element is a very important factor affecting the ultimate results. With even the best of equipment, efficiency depends upon the knowledge and technique of the personnel.

Openhearth furnaces were formerly operated by rule of thumb. The beginner in the shop was seldom permitted to look into the furnace or to observe the details of furnace practice. Training of new men was thus very slow, and openhearth knowledge was concentrated in the minds of comparatively few. Quite in contrast to this old attitude toward the new man, the beginner today is not only encouraged but urged to learn about furnace operation in the shortest possible time.

Maximum results are attained where the organization receives constant and intensive training in standard methods and practices based on the best available knowledge. The training program should also incorporate safety as well as technique. A well organized training program, consistently carried out, coordinates the work, teaches strict adherence to standard practices, and promotes uniformity of results. Waste is held to the minimum and the members of the organization are constantly reminded of the effect their particular workmanship has on the final results.

To be effective, the training program must be practical and specific. Group conferences, individual instruction by the foreman, frequent reviews and explanations of standard methods, will materially assist in developing a highly trained personnel.

Conclusion

The openhearth process has been in a constant state of development for some 60 years. At no time in its history has greater progress been made in quality and efficiency than in the past few years when economic conditions demanded all the ingenuity and resourcefulness of the operators. The process is based upon an enduring principle and its practice is constantly being improved, in pace with ever-increasing demands for greater efficiency and higher quality. It will continue to be an important factor in our great steel industry.

HIGH SURFACE FINISHES—

PREPARATION, SPECIFICATION,

AND EFFECT ON WEAR AND FATIGUE

Reported by Russell W. Dayton
Battelle Memorial Institute
Columbus, Ohio

SURFACE FINISH (means of measuring and specifying it, and determination of type of finish necessary for good performance of rotating and oscillating parts) is a subject of major industrial significance to a high speed age. Consequently a successful and stimulating Conference on Friction and Surface Finish early last month at Massachusetts Institute of Technology was most timely. About 200 people, including most of the well-known experts in the fields of surface finish, lubrication, and automobile and aircraft engine and bearing manufacture, were present, and each seemed anxious to contribute information to the common pool. As a result, the 18 scheduled hours of the three-day conference, and many unscheduled hours as well, were crowded. It is fortunate that the papers and discussions of this conference are to be published by the committee in charge (Professors HUNSAKER, LESSELLS, WILLIAMS and WULFF) so that one can have the opportunity of studying their context more closely than was possible during their presentation.

While "friction" was first on the announcement, the topic of surface finish was the focal point of the conference. Its most controversial phase concerned the desirable finish for various specific applications. It was generally agreed that crankpins should be "smoothly" finished because bearings seize more readily against "rough" shafts. (Quotes around qualitative terms are given only once, to avoid boring the reader.) The use of initially smooth shafts avoids in large measure the necessity for careful "wearing-in". However, it was not believed that rough surfaces caused appreciable wear of bearings. Smooth surfaces were also believed necessary when clearances are particularly "small", because the "initial wear" of a rough surface then is relatively great enough to be troublesome. J. O. ALMEN of General Motors Research Laboratory mentioned an outstanding case of this sort, that of fuel injectors for diesel engines, in which the clearance between piston and cylinder is 25 millionths of an inch, and exceptionally smooth surfaces are absolutely imperative.

LEONARD HOBBS of Pratt & Whitney Co. mentioned that smooth surfaces are necessary for "highly stressed" parts such as those of aircraft engines. In this case, all surfaces of stressed members are given "finely ground" finishes, with careful attention paid to scratch direction, to avoid stress raisers which would induce fatigue failure. An analogous comment was

that of HAAKON STYRI (S.K.F. Research Laboratories) who mentioned that "super-smooth" surface finishes are used on ball bearing races to prevent pitting, a form of fatigue failure. Surface finish may not always be as important as surface metallurgy, however, as ALMEN proved by showing that some sand blasted surfaces had higher fatigue strength than smoothly finished ones, because the hardening effect of the surface working overbalanced the roughening effect.

It was the consensus that smooth surfaces are not always desirable. Such an attitude was expressed by J. O. ALMEN and his associate A. F. UNDERWOOD, who felt that in services where galling might occur, rougher surfaces were desirable. RUSSELL W. DAYTON of Battelle Memorial Institute showed data on galling which indicated that "lapped" surfaces were sensitive to grit, while ground surfaces were not, and expressed the opinion that this lack of sensitivity may be the reason for the preference for roughly finished surfaces in some applications. The fact that piston rings invariably possess a turned surface to enable rapid seating and to prevent scuffing as well as blow-by, was brought out by several observers. It was mentioned that aircraft engine manufacturers will frequently give the finest possible finish to cylinder barrels, then roughen them slightly with emery paper so that rings will wear-in more quickly. Seating of the rings is aided by easily worn or soft coatings, as several speakers mentioned. After wearing-in, a ring should then wear but slowly. Apparently the joking comment of A. M. SWIGERT of the Chrysler Corp. that he found it difficult to understand how "a poor little piston ring could know when to stop wearing-in and to start wearing out" expresses aptly just what a piston ring must know.

Types of finishing methods were discussed by D. A. WALLACE of Chrysler's organization and others. Nevertheless, no evidence was presented to show that one type of finishing method was superior to another, as far as results in service are concerned. Apparently smoothness more than method of preparation decides the utility of a surface. One possible exception to this statement was pointed out by O. R. SCHURIG of General Electric Co., who showed that scratch direction on a bearing thrust plate influenced starting torque, the scratches running in the direction of motion causing less friction. J. T. Burwell, a student at M.I.T., presented data showing that initial wear of even the roughest steel shaft amounted to only a few millionths of an inch, and that the amount of it was nearly proportional to the surface roughness as measured by a profilometer.

The metallurgy of surface finish was discussed by Prof. JOHN WULFF, who showed that high speed, high pressure finishing methods caused "temperature flashes", and that high pressure methods caused surface deformation.

"Mirror Finish" of Improved Timken Roller Bearings, in Contrast With Finely Ground Surface Formerly Utilized. Cups are tilted slightly forward and photographed on checked fabric

On the soft stainless steel investigated, these effects penetrated to a considerable depth, about 0.0004 in. The temperature effects will probably be unimportant on most steels since, except on steels which anneal at low temperatures, there will be no metallurgical changes resulting from such temperature flashes. Furthermore, on harder materials than stainless, deformation will be confined to smaller

depths. The discussion of this work did not show whether or not these metallurgical changes influence the expected use of the metal part. One point of view is that the hardening effect of deformation will serve to prevent wear; the opposite view is that disturbed metal is undesirable.

STEWART WAY of Westinghouse Research Laboratories discussed methods of observing surface roughness, and the fundamental meaning of the results obtained by various methods. It appears to be very difficult to decide the character of a surface from any one method alone. He made the statement that scratches smaller than about 10 micro-inches could not be resolved by present methods. H. R. NELSON exhibited slides of the appearance of various types of surface as made at Battelle Memorial Institute by sectioning through a plated surface at a small angle, so as to magnify the surface roughness. This method (which is not very rapid), profilograph curves, profilometer readings and photomicrographs of the surface seem to be the most useful methods available at present for determining the amount and type of surface roughness.

Aspects of Wear

The scope of this conference was not limited to surface finish. Another favorite topic was wear. The present writer read a paper listing the known methods by which wear proceeds, including cutting, abrasion, corrosion, galling and fatigue failure. Men in the automotive industry discussed cylinder bore wear at some length and it appears that, in this country at least, cylinder bore wear is no longer a problem. J. O. ALMEN of General Motors felt that the high bore wear of foreign cars is due to low water jacket temperature, low piston ring temperature and insufficient ring tension, so that corrosive wear occurs. C. A. CHAYNE of Buick Motors said that it is possible to prevent wear almost entirely, either of rings or bore, by easing up slightly on operating conditions. He recommended surface coatings to wear-in rings rapidly and to prevent blow-by.

Bearings received a considerable amount of attention. The fundamental reasons for the usefulness of bearing materials intrigued many of those present. A. F. UNDERWOOD (General Motors) suggested that most of the useful bearing materials fell in certain groups of the periodic table. LEONARD HOBBS (Pratt & Whitney) mentioned his belief that materials which are difficult to bond to steel were good bearing materials. HANS ERNST and EUGENE MERCHANT (Cincinnati Milling Machine) thought that solid solubility played an important part. None of these suggestions constituted any answer to the question "What is a bearing material?" but they were interesting nonetheless. It was agreed by all that the older conception that hard and soft particles are a requisite of good bearing metals is not tenable.

Tests on bearings were reported, made in an effort to find the effect of finish on seizure. Two investigators reported that finish had a major effect, smooth shafts seizing at much greater loads than rough ones.

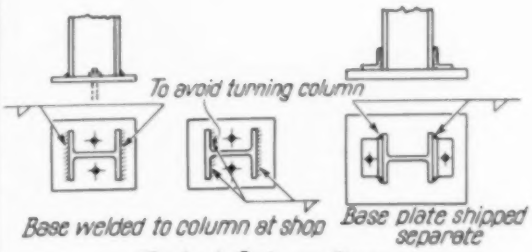
Boundary lubrication was discussed by G. B. KARELITZ of Columbia University and by OTTO BEECK of Shell Development Co. KARELITZ felt that true boundary lubrication was difficult to obtain, and described the failure of various static tests to duplicate service results. BEECK recommended a four-ball tester as a type of machine which did achieve true kinetic boundary film lubrication, setting as a postulate of boundary film lubrication that coefficient of friction be independent of both load and speed. Whether this is a true definition or not was a disputed point. BEECK described oiliness effects as being due to adsorption, EP ("extreme pressure") effects as due to chemical reaction. He felt that the function of a corrosive addition to make an EP lubricant was to react with high spots on the mating surfaces and remove them, rather than to deposit a film which kept the surfaces apart.

ERNST and MERCHANT also showed that the coefficient of friction between specially cleaned metal surfaces was much higher than reported in the handbooks, usually being in the neighborhood of unity. W. E. CAMPBELL showed that when greater precautions are taken to clean the surfaces, even higher values are obtained. Under conditions similar to those used by ERNST, CAMPBELL obtained practically identical values in his experimentation at Bell Telephone Laboratories. CAMPBELL also noted the effect of humidity on the coefficient of friction.

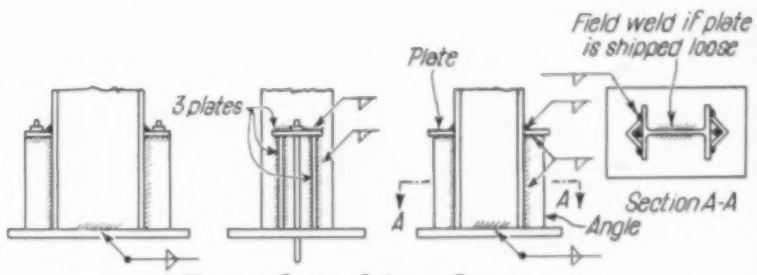
A great deal more information was presented than can be summarized in the space allotted for this sketch. In view of this, your reporter suggests that those interested in the subject of this meeting will benefit greatly by a study of the papers and the discussions, when they become available.

Welded Connections for Tier Buildings

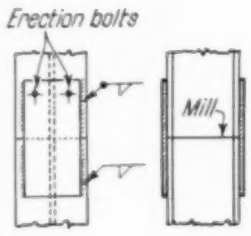
By permission, from American Institute of Steel Constuction's Tentative Standards, December, 1939



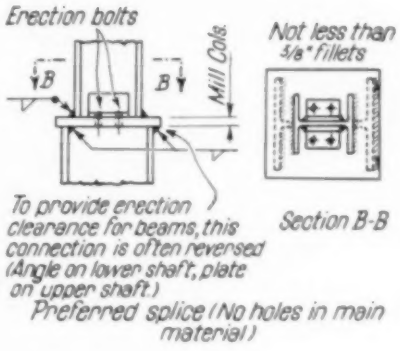
Typical Column Bases

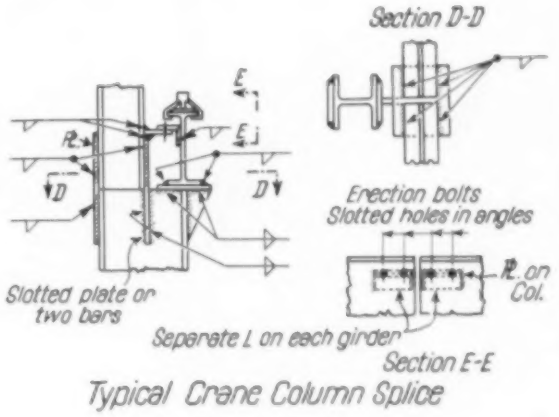


Typical Crane Column Bases

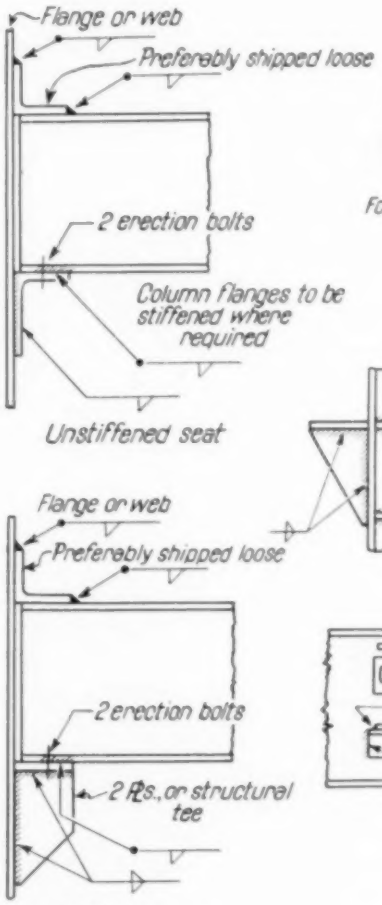


Typical Column Splices

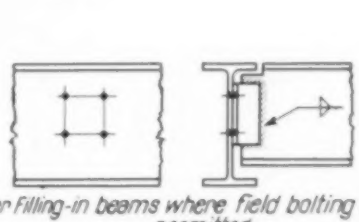

Erection bolts
B
Mill Cols.
To provide erection clearance for beams, this connection is often reversed (Angle on lower shaft, plate on upper shaft.)
Not less than 5/8" fillets
Section B-B
Preferred splice (No holes in main material)



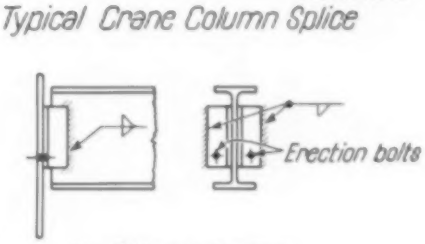
Typical Crane Column Splice

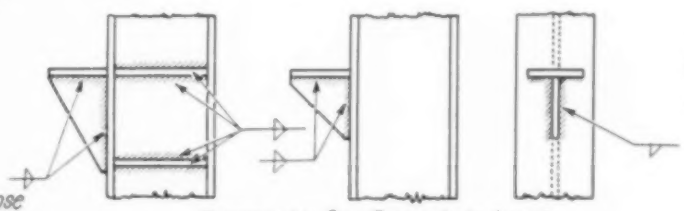


Beam to Column Connections

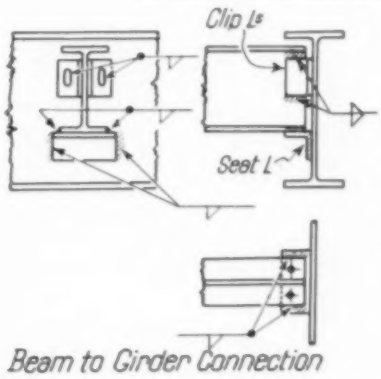


Typical Beam Details

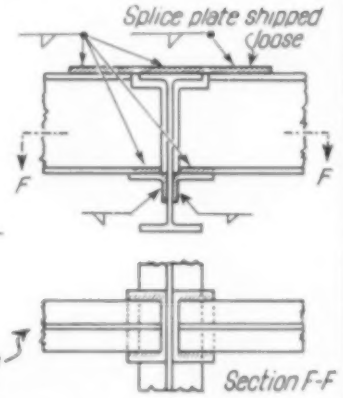




Brackets for Eccentric Loads



Beam to Girder Connection



Welds made with heavily coated electrodes only, and at temperatures above 25 °F. Fillet sizes ¼ or 5/16 in.; lighter fillets permissible on less than ½-in. plate. Welded structures must conform in design, fabrication and erection to American Welding Society's "Code for Fusion Welding and Gas Cutting in Building Construction." Rigid-end beams permissible only when specially designed for. Flexible beam connections shall permit rotation of top flange-ends an amount in inches equal to flexural unit stress in psi. at mid-span times span in feet divided by the constant 3,625,000.

MORE STRENGTH TO MEET STRESS...

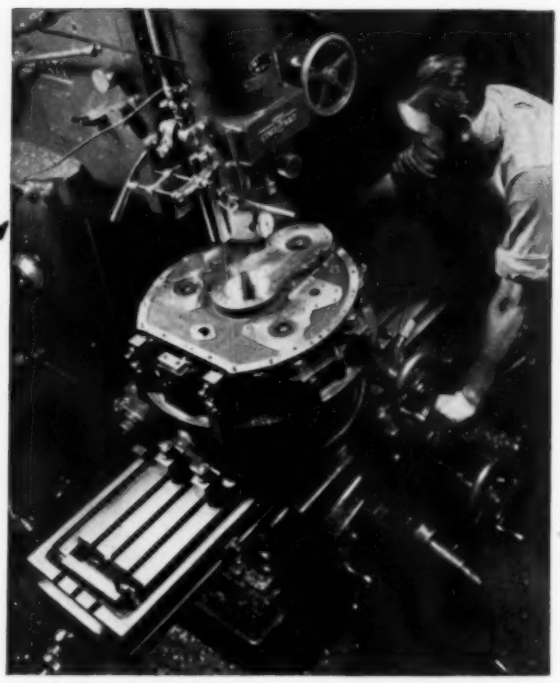
50 *places in a power shovel...*

85 *places in a rock drill...*

275 *places in a milling machine*

NICKEL ALLOY STEELS

Measured by weight, nearly ⅓ of this Bay City power shovel is fabricated from long-wearing Nickel alloy steels. 50 vital parts which must withstand fatigue strains, shock stress and overloads are made of SAE 3135 oil quenched Nickel-chromium steel and other Nickel alloy steels. Frames and bases are Nickel cast steel. "Chabelco" crawler drive chains, Diamond crowd chain, Hercules gasoline and Caterpillar Diesel engines on Bay City shovels also employ high strength Nickel alloy steels for important stressed components.



More than 275 stressed parts in this dial type Cincinnati milling machine are Nickel alloy steels. Nearly 200 of these parts are made of a Nickel-chromium steel, heat treated to high strength yet readily machinable. Parts subject to wear are case-hardened.

Here are five Gardner-Denver rock drills mounted for tunnel driving. In each drill, 85 stressed parts are produced from Nickel alloy steels. The Gardner-Denver Co. writes, "Through increased use of Nickel alloy steels, remarkable improvements in performance and reduction in maintenance costs have been accomplished—without comparable increase in weight or bulk."

• • •

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STATIC CRACK STRENGTH OF METALS

ITS DETERMINATION

AND SIGNIFICANCE

By Maxwell Gensamer
Associate Professor of Metallurgy
Carnegie Institute of Technology
Pittsburgh

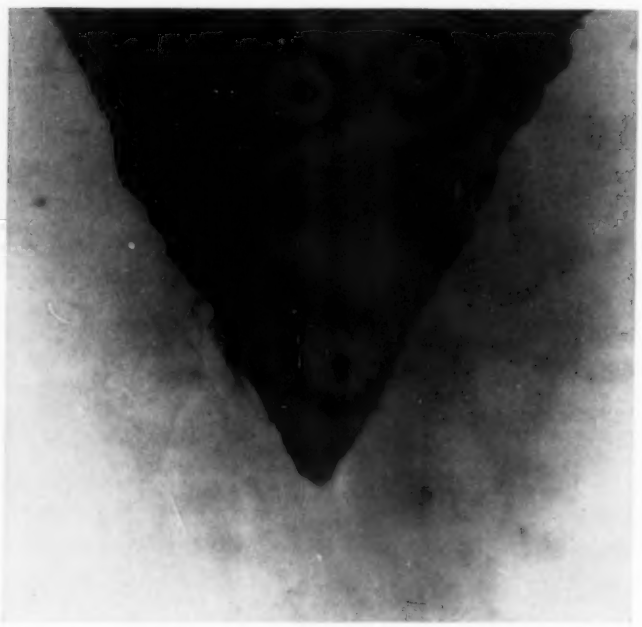
LAST FALL the author, in collaboration with ELIZABETH B. PEARSALL and G. V. SMITH, presented a paper to the annual convention, A.S.M., in which an effort was made to determine the stress-strain curve, the fatigue strength and the "technical cohesive strength" of eutectoid pearlite as the latter varied in interlamellar spacing. The paper (Preprint No. 26) was entitled "The Mechanical Properties of the Isothermal Decomposition Products of Austenite", and in it the cohesive strength was measured by a new technique which offered some advantages over the method used by W. KUNTZE, who proposed the test. The new method has aroused enough interest to justify a more detailed discussion.

More than ten years ago W. KUNTZE, basing his work on the fundamental researches and concepts of PAUL LUDWIK, developed a method for measuring what he called the "technical cohesive strength" of metals. LUDWIK had shown that the nominal stress (load divided by the cross-sectional area) required to fracture a notched specimen increases as the angle of the notch decreases — that is, as the notch is made sharper. At the same time, the amount of deformation preceding fracture decreases. W. KUNTZE, in *"Der Bruch gekerbter Zugproben"*, Report No. 129 to Verein deutscher Eisenhüttenleute, and in a 1932 book entitled *"Kohäsionsfestigkeit"*, showed that the breaking stress of such sharply notched specimens increases as the depth of the notch increases; that, in fact, yield strength, maximum load in the tensile test and stress at fracture all approach the same value as the notch is increased in depth and sharpness. This limiting value he called *"Trennfestigkeit"*, the "separating strength". Perhaps it ought to be called the "static crack strength". This value should be of interest to engineers, for it is the nominal stress required to propagate a crack in the presence of a very sharp and deep notch. Such a notch would be a crack running transversely to the direction of a tensile stress.

In KUNTZE's work, the nominal stress required to break a cylindrical bar in which a sharp 60° notch was machined to such a depth that the remaining area was 31% of the original was within 90% of the ultimate crack strength obtained by extrapolation. He called the breaking strength with this notch the "technical cohesive strength", and proposed that it be used as a practical measure of the crack strength.

The engineering value of the technical cohesive strength is unknown. One of the rea-

sons for this has been the difficulty of machining the necessary notches, perfectly sharp, especially in hard metals such as steel tempered to above Rockwell C-40. The author has been of the opinion that, if a technique could be devised to make the preparation of the specimens less time-consuming and difficult, it would be worth while to attempt to correlate service failures, notch sensitivity as measured in various other ways, and KUNTZE's technical cohesive strength. With this in mind, a study of methods for the production of sharp notches or cracks in hard steel was begun at Metals Research Laboratory, Carnegie Institute of



Cross-Section of Filed Notch in Hard Steel, at 1000 Diameters, Shows That the Radius at the Bottom Is on the Same Order of Magnitude (0.0001 In.) as the Tool Marks on Finish Machined Surfaces

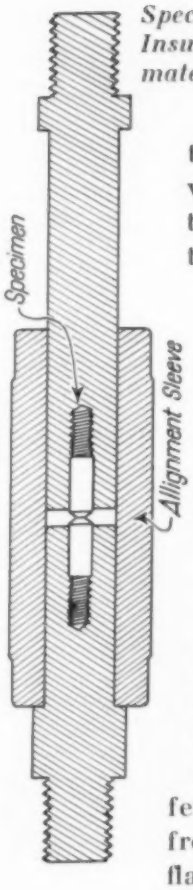
Technology. Success can be reported, for two methods have been developed that require little enough time and skill to be useful. Both start with machined 60° notches but do not require of this notch any greater sharpness or precision than can be achieved easily by any reasonably competent mechanic.

The first method consists of sharpening this machined notch by filing it with an ordinary 60° triangular file that has been smoothed (edge "sharpened") by rubbing two adjacent faces down on metallographic polishing paper or on a fine tool sharpening stone. During this smoothing operation the file surfaces are carefully held flat against the paper or stone to avoid rounding the corner. The last stroke at the bottom of the V-notch is done with a freshly ground corner. (This method was worked out by J. R. Low, research assistant in the Metal Research Laboratory.)

By this method sharper notches were obtained in steel Rockwell C-41 hard than by KUNTZE's machining method; the time required for filing is very little. A cross section through such a notch is illustrated in the first micro at 1000 diameters. It may be seen that the radius of curvature of the notch is roughly 10^{-4} in., — a tenth of a thousandth, comparable in magnitude to surface imperfections produced by machining. Perfectly "brittle fractures" without measurable plastic deformation were obtained with these filed notches. They are equal in sharpness to those produced by KUNTZE, and surely do not distort more metal than his. The trouble with the method is that considerable skill in filing must be developed.

The author raised the problem of the production of sharp notches or cracks for this purpose in conversation with Prof. A. V. DE FOREST of Massachusetts Institute of Technology, who suggested that it might be possible to produce circumferential fatigue cracks with controlled depth. It was not then known whether the processes involved in the production of a fatigue crack would have a greater or less effect on the crack strength of a metal than the processes involved in machining a sharp notch. With the assistance of a succession of graduate students, F. C. HULL, G. V. SMITH, J. R. LOW, and W. S. PELLINI, a technique has been worked out that quickly produces surprisingly regular fatigue cracks clear around the specimen of sufficiently reproducible depth and easily measurable area, and it has now been established that the technical cohesive strength measured by using these cracks as notches is substantially the same as that determined by using filed notches, and therefore the same as would be determined by KUNTZE's laborious method. The particular advantage over the filing method is that less manipulative skill is required.

The specimens used are small, originally cylinders 0.25 in. in diameter and 2 in. long; this is an advantage, for the smaller the specimen the more frequently it will be possible to obtain tests from machine parts that have failed in service. A smaller specimen than the one chosen would present some practical machining difficulties and would require special testing equipment. The ¼-in. cylinder can be machined on an ordinary lathe, cracked in a rotating can-



Specimen Holder (Neat Fits All Around) to Insure That the Cracked Specimen Is Ultimately Fractured by Axial Tension Stresses

tilever beam fatigue machine with collet chucks, broken in any testing machine having a sensitivity of 10 lb. in the range from 3000 to 6000 lb., and measured with almost any measuring microscope or comparator.

The specimen is threaded for a distance of $\frac{3}{8}$ in. from both ends, then notched with a 60° lathe tool to a depth of $\frac{3}{64}$ in. The depth of the notch is controlled with the micrometer scale on the cross feed screw of the lathe, and it is not necessary to measure the notches after machining. It is usually best to remove the last few thousandths of an inch with a freshly ground tool, dressed on a flat hand grinding stone. The next operation is polishing the notch with valve grinding compound or abrasive with grease, finishing with No. 400 carborundum. A little of the abrasive is rubbed into the notch as it turns in the lathe, pressing it in with a piece of soft wood such as balsa. This polishing operation is of some importance; without it, the fatigue cracks later induced are usually irregular in contour and quite eccentric with respect to the machined notch, so that results are erratic.

The fatigue crack is produced in a rotating cantilever beam fatigue machine equipped with collet chucks, with a capacity of 40 in-lb. bending moment, and operating at 10,000 r.p.m. It is convenient to use such a bending moment that the crack will be finished in from 10,000 to 20,000 revolutions, but this is not essential; there is no evidence that the number of revolutions used to crack the specimen has any effect on the technical cohesive strength measured. The depth of the crack is controlled by a micro switch placed under the end of the beam; the procedure has been to raise the switch with a screw until the machine stops, then back off the screw until the machine will just run. A slight circumferential fatigue crack will increase the deflection, touch the micro switch and stop the machine. It has been the practice to insure that the crack completely encircles the specimen by examining the base of the notch with a low power magnifier, slowly turning the specimen under a low bending moment; the region under examination is acted upon by a tensile stress which opens up the crack so it can be readily seen.

The cracked specimens are screwed into the adaptor illustrated in the adjoining sketch and broken in tension. The inside and outside surfaces of the end pieces of this adaptor are finished in one operation on a lathe, so that the hole into which the specimen fits (and this must be a neat fit) is exactly centered with respect to the outside surface. If this condition is met, then the heavy sleeve that slides over both the end pieces during the test insures that no bending moment is applied to the specimen. It is, of course, desirable that this device be used with self-aligning specimen holders. Properly cracked specimens break as the load is increasing; that is, there is no evidence of any yielding until fracture occurs. If the load reaches a maximum and begins to diminish before fracture occurs, the test is discarded, for this indicates plastic deformation preceding fracture.

Simple methods are now available for the determination of the technical cohesive strength (or static crack strength) of metals. It is therefore feasible for any laboratory to measure this properly and study its usefulness. This test may well explain some otherwise unexplained metallurgical failures in service.

On the fractured surface it is quite easy to distinguish between the fatigue crack and the crack produced in the final tension test, and the dimensions of this crack are easily measured with a comparator. It is convenient to have a simple chuck to hold the specimen so that it can be rotated to measure several diameters of the fractured area. The cracks are seldom perfect circles, but they are nearly always quite good ellipses. The area is then accurately figured from the product of the greatest and least diameter by

$$A = \frac{\pi}{4} \cdot D_{max} \cdot D_{min}$$

This assumption of an ellipse has been checked by comparing the areas so measured with the result obtained by a planimeter on a photograph at known magnification.

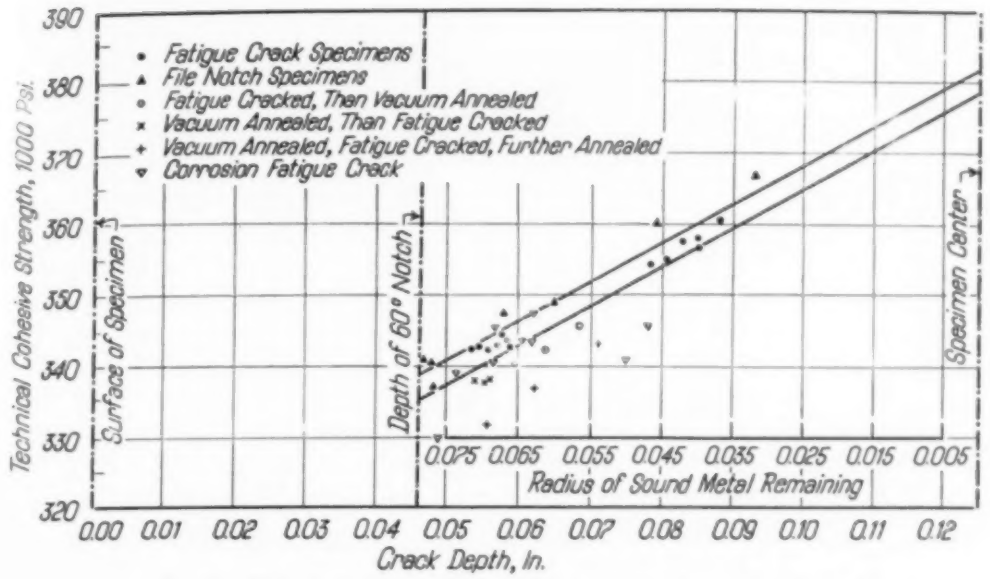
A typical fracture is illustrated, together with the fracture of one of the filed notch specimens. There is no evidence of plastic deformation in either of these fractures.

The effect of the depth of crack on the measured technical cohesive strength is shown in the first graph, in which the filled-in circles, all lying between the limits indicated by the dashed lines, represent all the test results obtained on a series of specimens prepared from one steel by the method described above. The material was a plain 0.80% carbon steel, quenched after 30 min. in lead at 825° C. (1520° F.) into lead at 400° C. (755° F.) and then cooled slowly to room temperature. The specimens are believed to have reacted almost completely in their 25-min. stay in the bath at 400° C. Rockwell hardness was C-41.5 ± 0.5. The graph shows the degree of reproducibility of the results as well as the effect of crack depth.

It also shows the results obtained with the filed notches. They lie consistently but only slightly above the results obtained with the fatigue cracks. Some of the test results on specimens with a filed notch were discarded because they broke under decreasing load indicating some plastic deformation prior to fracture. This was probably caused by failure to obtain a sharp notch. The difference between the results with the filed notches and fatigue cracked specimens is so slight that it may be considered demonstrated that the fatiguing process may safely be used instead of KUNTZE's method. The dimensions of the specimen have been so chosen that a crack 0.01 in. deep leaves an area beneath it of 31% of the original area of the cylinder. A variation of depth of ±0.005 in., within which range it is not difficult to control the depth, may be expected to give a variation in technical cohesive strength of ±5000 psi., which is accurate enough and within the range to be expected from the scatter of the test results.

It will be observed that these results, indicating a technical cohesive strength of about 285,000 psi., extrapolate to a value of about 360,000 psi. for zero remaining area under the crack. The technical cohesive strength is then only 80% of the static crack strength for a very deep crack, instead of the 94% claimed by

Fractures of Sharply Notched Specimens of a Single Steel After Testing for Technical Cohesive Strength. Magnified 15 diameters. Note annular fatigue crack around broken area in the view at the left; the other specimen was cracked after filing a sharp notch

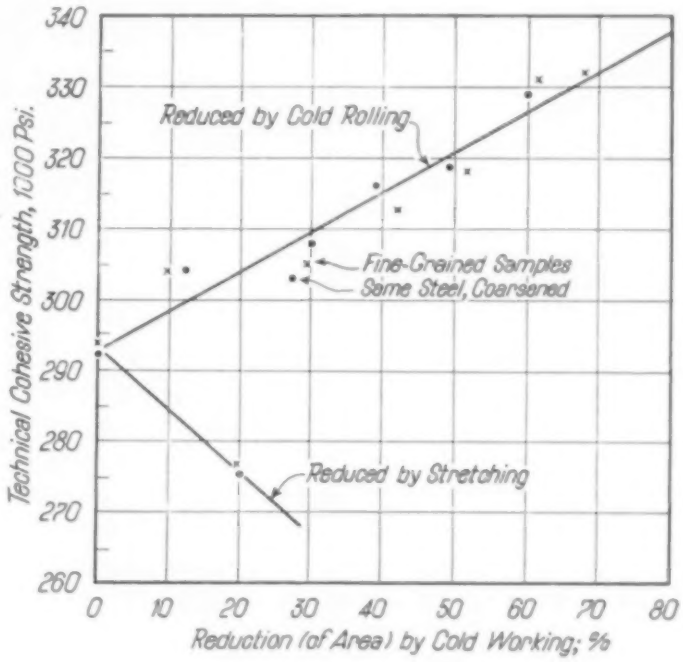


The Technical Cohesive Strength in a Fatigue Cracked Specimen Is Slightly Lower Than in One With a Machined Notch. Depth of notch increases the test result and vacuum annealing lowers the result, presumably because it softens the steel

KUNTZE. Whether this difference is caused by material or technique remains to be shown.

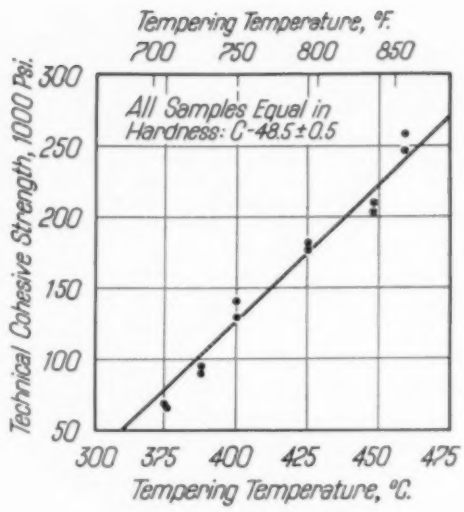
Also shown on the same figure are some results on specimens that have been annealed in vacuum after the cracking operation and some on specimens in which the crack was produced under corrosive conditions. The purpose of these tests was to see if the fatiguing process changes the technical cohesive strength of the material; if it does, then annealing or accelerating the progress of the crack by corrosion should change the results. The corrosive agent used in producing the corrosion fatigue cracks was 0.1 normal hydrochloric acid fed to the specimen by a strand of cotton attached to the tip of a burette; the bending moment was reduced from 28 to 25 in-lb., and only 1000 to 2000 reversals were required to produce the crack instead of the usual 10,000 to 20,000. With shallow cracks no significant effect on the technical cohesive strength was observed. Unfortunately annealing reduces the hardness of the samples and consequently the technical cohesive strength, as shown by GENSAMER, PEARSALL, and SMITH in the ⊕ paper last fall. Annealing was carried out in a very good vacuum at 380° C., 20° below the reaction temperature used in heat treating, and the specimens were at temperature about 14 hr. A single anneal reduced the hardness from Rockwell C-41.5 to C-37. Repeating the anneal, as with the group of specimens giving the lowest results, still further reduced the hardness to C-35.5 Considering this softening effect, it would seem fair to conclude that the fatiguing process (as well as the machining process) has changed the technical cohesive strength relatively little, but probably some.

A few entertaining results have been obtained by this method. Cold work affects the technical cohesive strength, as shown in the graph at the bottom of this page; it is raised by cold rolling and lowered by stretching in tension. The important fact is that the state of stress prevailing during plastic deformation affects the static crack strength. In this same series of tests an effort was made to correlate static crack strength with impact strength, by coarsening the austenite grain size of one group of samples of homogenized S.A.E. 4140 and comparing the properties of this coarsened steel with those of the same steel in the fine-grained condition. The grain sizes devel-



The State of Stress Prevailing During Prior Cold Work Has Considerable Influence, and the Technical Cohesive Strength of Heat Treated S.A.E. 4140 (Rockwell C-39.5 ± 0.5) Is the Same Whether Fine Grained or Coarse Grained. (Tests performed by graduate students E. F. Losco and C. E. Lacy)

oped were A.S.T.M. No. 3 and 7; both groups of specimens were quenched and drawn to Rockwell C-39 to 40, with a tensile strength of 178,000 psi. Stress-strain curves and fatigue strength were almost identical. The fine-grained steel had a Charpy value of 36 to 37 ft-lb.; for the coarsened it was 25 to 28. Both fine and coarse samples had a technical cohesive strength in the range from 290,000 to 300,000 psi., and the graph shows that the technical cohesive strength of both was changed the same amount by cold working. The difference in notch toughness indicated by a Charpy test and caused by coarsening the austenite during heat treatment was *not* reflected in the technical cohesive strength. It *was* reflected, however, in the reduction of area and elongation in the tensile test, which were 53% and 16% respectively for the fine-grained steel and only 40% and 13% for the coarsened.



The Cohesive Strength Varies Widely Even Though Hardness Is Constant, Depending on Time and Temperature of the Tempering After Quenching. (From a senior thesis prepared by C. F. Cieslicki)

As illustrated in the last diagram herewith, technical cohesive strength can vary over a wide range in quenched and tempered steel of the same hardness, depending on the time and heat of the tempering. An 0.80% carbon steel was quenched and tempered to Rockwell C-48, using tempering treatments ranging from 30 sec. at 465° C. (875° F.) to 50 min. at 350° C. (660° F.); the technical cohesive strength varied from 250,000 psi. for the highest temperature used to 70,000 psi. for the lowest temperature and longest time. It would appear therefore that, at least in eutectoid carbon steel, the *method* of acquiring the desired tensile strength, hardness and impact strength, may have a great influence on its ability to resist a spreading crack — that is to say, on its technical cohesive strength. Experiments on the *aging* of quickly tempered steel of this hardness are in order; a technical cohesive strength as low as 70,000 psi. in such a material as a heat treated bridge wire would obviously be dangerous.

MECHANICAL EFFECTS OF GRAIN BOUNDARIES

By Martin Seyl

ORDINARY metallurgists may be pardoned for not having a very clear picture of the atomic organization of the matter at the grain boundaries in their metals, but it may be news that the modern physicist is no more confident of himself when he finds himself in that region. It is commonly said that the mechanical properties of a metal are greatly influenced by its grain size, with the inference that the material at the grain boundary has a lot to do with it. The usual, but vague, explanation of this effect might be as follows: Plastic deformation in metal crystals is accomplished by means of slip along certain crystallographic planes, and in a single crystal test piece the path of this slip proceeds along a substantially unaltered course through the cross-section. (Stop here long enough to consider the implications of a possibility that slip might start simultaneously from two opposite sides of the crystal on planes that do not exactly register, and the motion work rapidly across but meet and stop near the center.) Now, in a polycrystalline test piece the path of completely transcrystalline slip is altered at grain boundaries, as a result either of obstruction material in these boundaries or of the circumstance that the surrounding grains have different orientations. Since the path of

slip is more devious through a polycrystalline material, such material will have a greater resistance to plastic deformation. Likewise, resistance to plastic deformation increases as the grain size decreases, for the number of such grain-boundary interferences correspondingly increases.

The question is one obviously of practical as well as theoretical importance, so Dr. BRUCE CHALMERS marshalled the available evidence on "The Mechanical Effects of Intercrystalline Boundaries" at a recent meeting reported in the 1940 *Proceedings* of the Physical Society (London). At the outset he points out "that numerous direct investigations of the effects of grain size, while having the greatest practical interest, cannot be used as the basis for fundamental considerations. There are several reasons for this, of which the most important is that when a variation in grain size is brought about by mechanical and thermal treatment, there is a likelihood of some other change also occurring, such as the introduction of internal strain, the production of a preferred orientation, a change in shape of the grains, or a change in the distribution or equilibrium of minor constituents. Further, it may be necessary to distinguish between absolute grain size and relative grain size, that is, the size of the crystal expressed in relation to the dimension of the test piece."

Granted that this is true, we should see what comfort can be got from the "laws" of plastic deformation in single crystals which are recopied in most scientific books that mention the subject:

1. Shear takes place in crystallographic directions of a type which, in the case of a given metal at a given temperature, is fixed.

2. Shear usually takes place on planes of definite crystallographic type.

3. Shear takes place in one of these directions when the shear stress in that direction reaches a value that is characteristic of the material and its previous history.

4. This critical shear stress is independent of the tension in a direction perpendicular to the shear direction.

To translate these general conclusions about large single crystals to polycrystalline test pieces, help may be had from the investigations by GOUGH and his collaborators at the National Physical Laboratory in England on the effects of alternating torsional stresses on aluminum specimens containing only a few crystals. They concluded that glide takes place in any one crystal in the same directions and on the same planes as it would if the specimen consisted of that crystal only.

Illuminating, also, is some of CHALMERS' own work on cylindrical test pieces of tin containing two crystals with their boundary running the full length of the specimen. Their yield stress varied in a regular and approximately linear way with the angle between the *c* axes in the two crystals making them up. The extremes of this variation are considerable; for a specimen in which the angle between the *c* axes of the two grains was 90°, the yield strength was 60% greater than for a single crystal. This seems to suggest to Dr. CHALMERS that "there is no specific boundary layer or material with a definite mechanical effect of its own, and that the increased yield stress of polycrystalline metal is due to a secondary effect."

In other words, grain boundaries in a relatively pure metal do not in themselves modify the stress-strain characteristics of the crystals, but an adjacent grain raises the stress required to *initiate* slip to an extent dependent on its relative orientation. This is done without altering the operative slip directions and planes.

However, this conclusion does not appear adequate for a polycrystalline aggregate where the grains are much smaller. For example, TAYLOR postulates that a grain in a sample of polycrystalline aluminum may employ as many as five slip systems when deformed in simple tension. Furthermore, the work of ANDRADE and CHALMERS on polycrystalline cadmium indicated that plastic flow was accomplished in two stages; in the first stage the deformation was associated with slip on crystallographic planes and with crystallite rotations, but "after a certain amount of glide has taken place, the ability of the crystal to glide along the permissible planes has decreased to such an extent that this type of deformation no longer occurs. Subsequent deformation must then be of the kind that takes place in amorphous materials, shear occurring in all directions inclined at 45° to the direction of stress."

What this all leads to is still a dim problem for the future, but it pretty clearly indicates that the supposed influence of grain boundary material (if any) on the elastic properties and plastic action of structural metals has been unduly magnified. Indeed a metallurgist, and even a physicist, may blush and stammer a bit when trying to reply to the question, "What is a grain boundary?"

CORRESPONDENCE & FOREIGN LETTERS

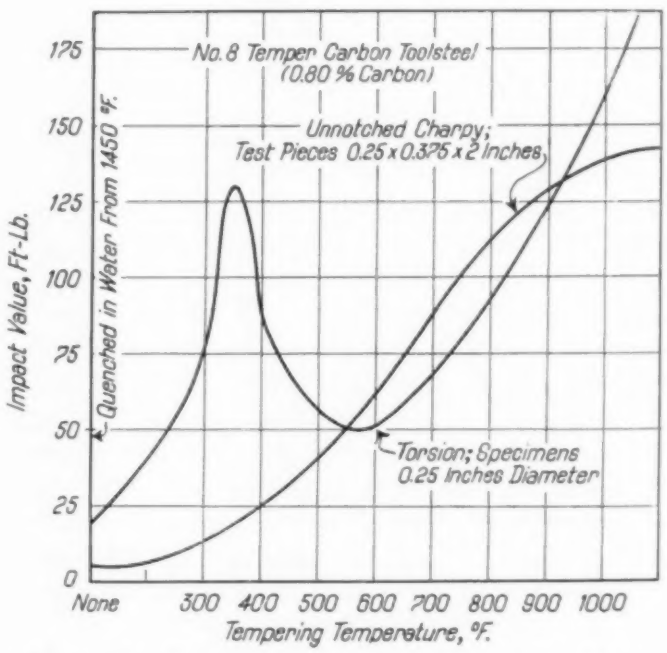
Toughness of Toolsteels

Special letter to METAL PROGRESS
by NATHAN LEVINSOHN
Assistant Metallurgist
Minneapolis-Moline Power Implement Co.

ST. PAUL, *Minn.* — I read with great interest ROBERT S. ROSE's article on "Toughness of Toolsteels" which was published in the April issue of METAL PROGRESS. The manner in which he defines and describes toughness was very well done.

He states that 18 specimens of carbon steel were heat treated for maximum toughness by various manufacturers of steel products. "No stipulation as to hardness or any other physical properties were made, just 'maximum toughness'." It is therefore logical to assume that those plants which were familiar with the curve on page 410 of METAL PROGRESS, reproduced herewith, would temper the specimens at approximately 350° F., and thus obtain maximum toughness with very nearly maximum hardness. However, if the steel specimen were heat treated mainly for maximum toughness, a tempering treatment which will produce a sorbitic microstructure would result in maximum toughness and a low hardness of approximately C-40 to C-45. One may therefore produce maximum toughness with low hardness, or maximum toughness with high hardness, depending upon what tempering treatment the hardened specimen is given. This may explain why the 18 specimens which were heat treated by the various manufacturers showed a hardness range of Rockwell C-45 to C-62.

Mr. ROSE calls our attention to the statement that "Torsion tests have indicated peculiar and high toughness values (in straight



Curves by Courtesy of Bethlehem Steel Co. Showing Diverse "Toughness" Values for a Carbon Toolsteel Tempered at 300 to 450° F., Depending on the Type of Impact Test. (Reproduced from Mr. Rose's article in April METAL PROGRESS)

carbon steels with specific tempering treatments) not shown when test pieces are loaded in tension, transverse, or flexure. . . . . The notched bar Charpy and Izod tests are of no value in the testing of steels of high hardness. . . . . ." This statement also conforms to the results published by Messrs. LUERSSEN and GREENE, in their paper on "Torsion Impact Testing" in *Proceedings* of the American Society for Testing Materials, II, 1933, p. 315. These indicate that torsion impact testing of carbon toolsteels, having a carbon content of 1.06%, shows increased toughness in the tempering range 350 to 400° F. and that Izod tests on both notched and unnotched specimens did not show this maximum toughness.

However, in an investigation made by R. L. DOWDELL, professor of metallography at the University of Minnesota, and myself, we found that the toughness of toolsteels was very easily measured by the Charpy impact test, regardless if made in tension or on notched tests in bending. A summary of the work was published in the *Bulletin* of the American Society for Testing Materials for December, 1935, from which the adjoining curves are taken showing conditions for an 0.86% carbon toolsteel quenched from 1438° F. and tempered 60 min. at the indicated temperature.

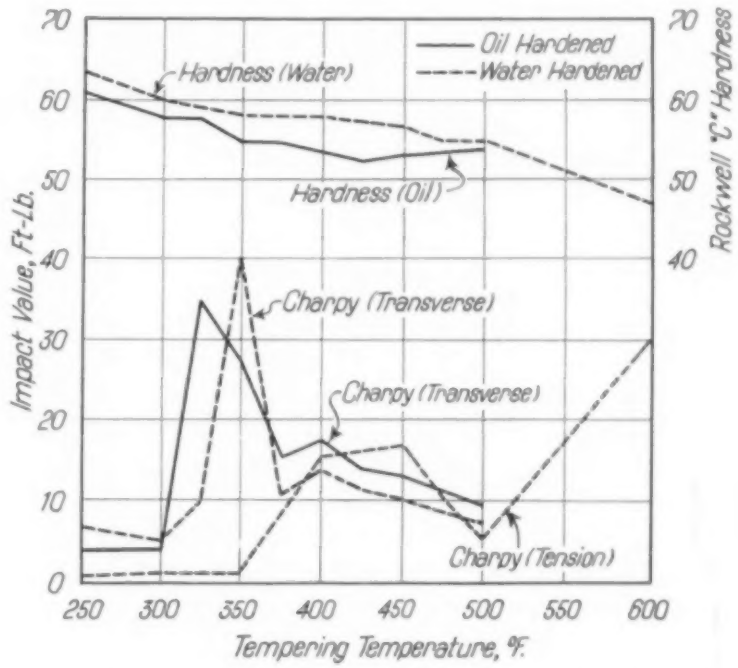
The transverse impact specimens were 1 cm. (0.395 in.) square and 2 in. in length. After forging, annealing, hardening and tempering the bars, a very soft grinding wheel was used to remove several thousandths inches of the material. After machining the specimens, notches were ground in with a commercial "cutting-off" wheel designated Alundum—Shellac, 80 N5L. They were $\frac{1}{16}$ in. thick. The notches were 0.075 in. deep, which was considered sufficient to localize the stress and fracture. The grinding wheels give a practically constant radius at the bottom of the notch of 0.037 in.

The specimens used in the impact tension tests were machined to 0.236 in. diameter from ¾-in. round annealed stock, followed by hardening and tempering. A 2-in. gage length was used.

NATHAN LEVINSOHN.

Mr. Rose Replies

Mr. LEVINSOHN suggests in the first portion of his discussion that those familiar with the curves reproduced from my article on page 410 of the April issue would temper quenched carbon toolsteel at approximately 350° F. to obtain maximum toughness. It appears to us that only the *torsion* curve is so indicative, with the unnotched Charpy showing a relatively low energy value at this drawing range. Moreover, if to these is added the tension impact from Mr. LEVINSOHN's own data, still another optimum tempering range (400 to 450° F.) is indicated. In fact, his curves show maximum transverse impact values at minimum tension impact values, and vice versa.



Test Bars of Hardened 0.86% Carbon Toolsteel Tested in Charpy Machine (Notched Transverse Specimens or Unnotched Tensile Specimens) Show Superior Energy Absorption ("Toughness") After the 300 to 450° Temperings

Our objections to notched Charpy and Izod tests of hardened toolsteel are manifold. Usually the values are low with great variation between duplicate specimens. This can be expected with material of high shear strength when loaded under conditions wherein the ratio of normal to shear stresses is above 2 to 1. Mr. LEVINSOHN's specimens presumably were not the so-called standard keyhole Charpy, but even so his values are surprisingly high.

It would be interesting to learn the number of tests made, whether any specimens of other dimensions were tested, and the variation in values between specimens of the same dimension.

ROBERT S. ROSE
Manager, Boston District
Vanadium-Alloys Steel Co.

Names for Steel's Microconstituents

Special letter to METAL PROGRESS
by NICOLAS T. BELAIEW
Consulting Engineer
Institut de Soudure Autogène

PARIS, *France* — The death of ALBERT SAUVEUR about 18 months ago has caused a drop in the interest this dean of metallurgists was exciting on the problem of correct metallographic nomenclature. It will be recalled that at that time he had circulated a questionnaire to prominent metallurgists, sounding out world opinion as to the desirability of a conference on this matter. At the present time it may do no harm to point out that the matter is still an open question.

As far as I am informed, CHARLES Y. CLAYTON first raised the question in an American publication (METAL PROGRESS, March 1934, p. 43), posing the question "How may we distinguish between pearlite, sorbite and troostite, as observed under the microscope?" CLAYTON seemed to hold for the retention of the old terms, adding the qualifying adjectives "primary" and "secondary". (The terms primary and secondary troostite are in rather wide current usage in metallographic literature; they were adopted by HANEMANN in his "Atlas Metallographicus", and quite recently by CARPENTER and ROBERTSON in their latest work on "Metals".) At the same time, CLAYTON introduces a table showing the differences of interlamellar distances, Δ_0, of the constituents, a conception introduced by the present writer some years previously. Thus there seems to be a means of distinguishing by measurement.

The problem of nomenclature was really brought to the fore by E. C. BAIN, J. R. VILELLA and G. E. GUELLICH in their paper presented before American Society for Metals, published in June 1936 in the *Transactions* under the title "On Naming the Aggregate Constituents in Steel", and fully abstracted in METAL PROGRESS for August, 1935, an issue containing other notable articles on the same problem.

In this article BAIN and his collaborators propose that the term pearlite be applied to *all* the lamellar structures formed of ferrite and cementite on cooling and obtained directly from the austenite by "nodular growth from nuclei at comparatively high subcritical temperatures" between, say, 1300 and 1000° F. On the other hand, they reserve the term sorbite for the products of the decomposition of martensite on heating ("tempered martensitic structures"). As to troostite, this word was to be eliminated.

In a later publication by VILLELLA (*Metals and Alloys*, September, 1938) the term "bainite" was proposed for the product of isothermal transformation at temperatures below the lower limit for fine pearlite, and above the higher limit for martensite.

Modern French practice would follow PORTEVIN and JOLIVET in distinguishing three modes of transformation:

1. Transformation in the upper zone, nodular mode — pearlite or nodular troostite.

2. Transformation in the intermediate zone, acicular mode — acicular troostite. (See PORTEVIN's letter in METAL PROGRESS, June 1939).

3. Transformation in the lower zone, martensitic mode.

Practice in England is also veering to the same view of PORTEVIN and JOLIVET's that there are in essence *three* locations for the critical point in carbon steel, depending on the amount of suppression by more and more rapid cooling, namely Ar′, Ar″ and Ar‴, where Ar‴ takes place of the old Ar″ noting the beginning of martensitic transformation. (See the report by GRIFFITHS, PFEIL and ALLEN abstracted in METAL PROGRESS in August 1939.)

Returning now to the problem of exact nomenclature, it would indeed be desirable to be more precise. The distinction between the constituents is subtle, lacking in precision, and varies with French authors. Oftener than not, it is not made.

For the moment we have three principal suggestions before us: The first, from SAUVEUR, is to retain the names pearlite, sorbite and troostite, adding the appropriate definitions lamellar or granular. The second, from BAIN and his associates, is to extend the name pearlite to the entire lamellar series and adopt the name sorbite for the granular structures. The third, from CLAYTON, is to introduce the concept of interlamellar distance as a ruling magnitude.

Such quantitative conceptions should be useful in the study of lamellar structures. In the first place, BAIN himself, while abandoning the terms sorbite and troostite, is forced to resort to such characterizations as medium, fine and very fine pearlite, while ROBERT F. MEHL in his article on "The Physics of Hardenability", , October 1938, published interesting diagrams on the constancy of the interlamellar distances,

A_0, and uses this method of studying the formation of pearlite.

In introducing this conception, the present writer long ago found that the ordinary lamellar pearlites have lamellar distances between 300 and 350$\mu\mu$, while the troostites have lamellar distances of only 100$\mu\mu$. The sorbites, (the fine pearlites of BAIN) have A_0 less than 250 to 260$\mu\mu$. A gap seems to exist between the sorbitic dimensions and those of troostite. On the other hand, a marked difference can be observed between the pearlites coarser than 250$\mu\mu$ and the sorbites finer than 250$\mu\mu$.

In closing, may I express the hope that the revision of our nomenclature can be achieved with the minimum of departure from the views of OSMOND and HOWE and from the current practice which follows them, continuing to make use of the terms pearlite, sorbite and troostite for structures formed on cooling and, by extension of this reasoning, to use the term osmondite for the products of tempered martensite.

NICOLAS T. BELAIEW

High Speed Impact Testing

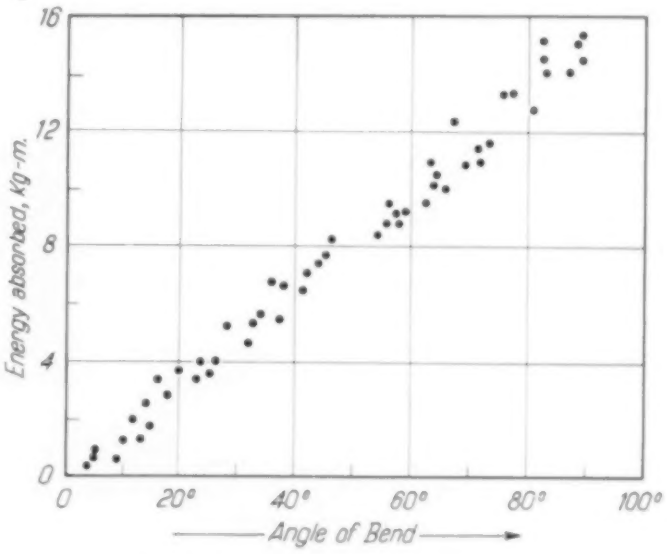
Special letter to METAL PROGRESS
by N. DAVIDENKOFF
Professor
Physico-Technical Institute

LENINGRAD, *U. S. S. R.* — Continued interest in the relationship between "toughness" and "impact testing" is evident from current American technical literature, and will be some justification for some notes on a continuing investigation of cold brittleness of steel by the writer and his associates at the Physico-Technical Institute. (A brief account of the work up to 1937 was published in that year in *Metal Industry* of London, England, and a detailed analysis of "The Impact Problem in the Science of Metals" is given in a monograph in Russian by the present author published in 1938.)

One of the main problems was to determine the relationship between the rate of deformation and the critical temperature of brittleness over a wide range of temperatures and velocities. ("Critical temperature of brittleness" refers to that temperature range above which the test specimens require much work to fracture, and below which they break with little difficulty.) For this purpose a special high-velocity impact machine had to be constructed in which the velocity of the striking edge would reach 325 ft. per sec. The chief difficulty lay in the impossibility of measuring in a direct way the energy absorbed, since *(a)* at these high velocities the kinetic energy spent in brushing aside the fragments is of the same order of magnitude as the energy required for rupture, *(b)* the loss of velocity of the striking head upon rupture of the specimen is so small that its accurate determination requires rather complicated methods, and *(c)* the use of a ballistic pendulum of the MANN type would certainly lead to erroneous results. It was therefore thought more rational to measure the deformation of the specimen; this, at the given velocity, was expected to be directly proportional to the energy absorbed during fracture.

This proportionality was verified by a series of experiments, using an ordinary CHARPY pendulum. In the case of unnotched specimens, the angle formed by the two halves of the specimen when put together after rupture, was taken as a measure of the deformation. The first diagram is one of many others that were determined, all showing the close proportionality between the above angle and the energy absorbed, when testing is done at ordinary velocities.

Returning now to our problem of studying impact at a high velocity, a machine was constructed in our laboratories by F. WITTMANN. It was similar to the GUILLERY machine, of the flywheel type, but the ordinary velocity of about 30 ft. per sec. was increased ten fold. Cylindrical unnotched specimens, made of coarse-



When Unnotched Charpy Test Pieces Are Broken and Reassembled, the Angle of Bend Is Proportional to the Energy Absorbed

grained mild steel, were then submitted to test. The rate of deformation (percentage elongation) varied from 1% per sec. in the static tension test to 130,000% per sec. in the fastest impact test we have made.

The results obtained above the critical temperature of brittleness fit the equation

$$\log V = A + (B \div T_k)$$

where V is the rate of deformation in per cent per sec.

A and B are constants

T_k is the critical temperature of brittleness (absolute scale).

A similar straight line, except for its slope being different, was obtained in the case of notched specimens. This graph characterizes the comparative brittleness of various kinds of steel and should be of prime importance to the construction engineer, especially if he is to base his computations on the "brittleness factor", as proposed in the author's contribution to the 1938 Symposium on Impact Testing held by the American Society for Testing Materials.

N. DAVIDENKOFF

The Forgeability of Steels

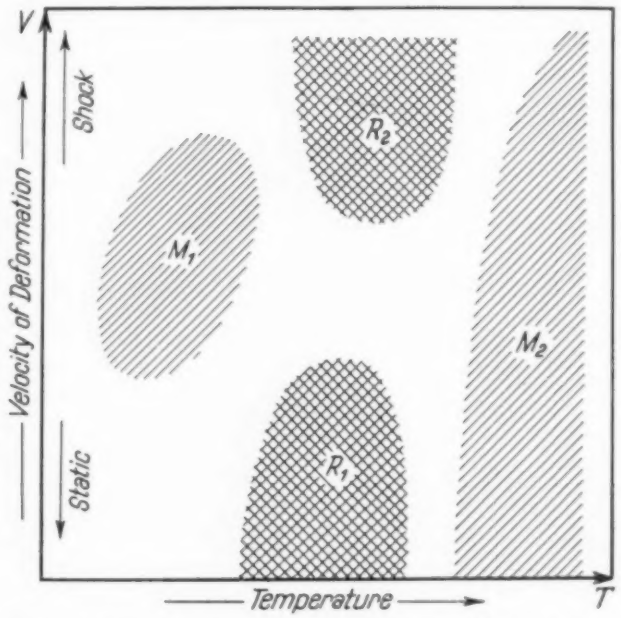
Special letter to METAL PROGRESS
by ALBERT M. PORTEVIN
Consulting Engineer; Bessemer Medalist

PARIS, *France* — We have noted in METAL PROGRESS, May 1937, page 531, that studies carried on with DE LACOMBE have led to the selection of the notched bar bend test for ascertaining the forgeability of steels.

Conclusions drawn from this test have been found to agree with practical experience, on the condition that the rate of straining in the test is extended over as wide a range as possible. A method is thus provided for studying forgeability by means of laboratory tests on small specimens under well-defined and constant conditions of temperature, rate, surface condition and atmosphere. It allows for numerous determinations, the accumulation of results and, at the same time, consumes a comparatively small quantity of metal which may consequently be obtained in the homogeneous state. This combination of conditions and advantages is seldom — we might say never — realized in practical tests in the forge shop.

With the thought of undertaking a systematic study of factors affecting the forgeability of steels — particularly those practical factors which are disputed, unexplained or even unknown — a series of studies has been pursued from which we might make a few observations in a simplified and schematic form.

1. First of all, if we consider pure carbon steels (the impurities sulphur and phosphorus neither exceeding about 0.02% and containing only about 0.03% manganese) there seem to exist two zones of malleability M and two zones of rupture or of non-forgeability R, when the test temperature T and testing rate V vary. On constructing a diagram showing the curves of rupture f as a function of these two variables, a surface having a double curvature is obtained with two regions M_1 and M_2 having high values of f indicating zones of forgeability, and two



Forgeability of Pure Carbon Steels, When Plotted Against Velocity of Deformation and Temperature of Metal, Produces a Surface Having Two Regions M of High Malleability or Forgeability, as Well as Two Regions R of Fragility or Brittleness

regions R_1 and R_2 with low rupture deformation. It was noted that all carbon steels corresponding to this type of diagram are susceptible to red shortness when hot worked by forging or rolling. This clearly indicates that the expression "forgeable steel" is definitive only when the rate of deformation, as well as the temperature is taken into consideration.

2. Manganese is reputed to be the element whose addition pre-eminently improves or induces forgeability (titanium and zirconium would also have the same effect). It would seem, according to the first results obtained,

that the addition of manganese would suppress the brittle or rupture zone R_2 corresponding to high testing rate, leaving only the lower zone marked R_1 on the diagram, page 70.

Steels corresponding to this condition are free from red shortness on forging or rolling. It appears, then, that the R_2 zone is the characteristic zone of red shortness. (This observation is true only for carbon steels and should not be applied, for instance, to the austenitic or eutectic steels.) Furthermore, manganese facilitates the reduction of inclusions by aluminum; a non-forgeable steel without manganese contains globular inclusions of silica or aluminum silicate depending on whether or not some aluminum was added to the molten steel; in manganese steels the inclusions are manganese silicate which can be reduced by aluminum giving rise to clusters of alumina (see letter published in METAL PROGRESS, January 1939, page 68).

3. The properties of hot rupture of carbon steels, as defined above, are little modified by working. They are often almost the same in the metal as-cast and in the heavily worked condition. Rather than being influenced by hot work, they are sometimes definitely a function of the preliminary heat treatment.

4. Surface condition has a great influence on forgeability, for the cracks that make a metal non-forgeable start from the surface. This is also the origin of the well-known troubles caused by the presence of certain metals in the surface, such as tin, antimony or copper. On the other hand, by malleableizing the surface of a non-malleable metal, it is possible to forge the whole, or to improve the forgeability of an alloy that is only slightly malleable; this is what takes place when highly carburized toolsteels or white cast iron are slightly decarburized at the surface.

The forgeability of these products can likewise be improved by coalescing the eutectic structure of which they are largely composed. This may be done by the forging action itself in its first stages ("saddening") or by preliminary heat treatments which are, however, generally difficult to execute.

5. Finally, these laboratory tests show the sudden and reversible change in mode of rupture evinced by as-cast ferrites, high in chromium, at a temperature of only about 400° F. This phenomenon is important in castings and I shall discuss it again later.

ALBERT M. PORTEVIN

Austempering Improves Valve Springs

Special letter to METAL PROGRESS
by ALBERTO OREFFICE
Chief Engineer, Steel Department of the Fiat Co.

TURIN, *Italy* — In two previous letters (printed in METAL PROGRESS in March and December 1939) I have pointed out that the Fiat Co. utilizes a specification for valve spring wire for aero-engines that sets up requirements as to ultimate tensile strength and alternate torsions to 180° in specimens of length 50 times the wire diameter. Representative values would be for 0.177-in. wire: 234,000 psi. ultimate and 180 alternate torsions (both minimum values). In the second letter I communicated our tests indicating that a superior spring wire had been secured that practically doubled the alternate torsions, and at the same time had, when quenched and tempered, a high endurance limit: 0 to 84,000 psi. in torsion (not "tension" as printed in the December note).

We now find that the special hardening procedure known as austempering gives a further large increase in alternate 180° torsions before failure, and therefore represents an important step in the progress of spring manufacture. The tests are indeed astonishing, since the new heat treatment about doubles the torsions, and it is our experience that this figure should be high if the finished spring is to give long service. We find, for instance, that Swedish oil tempered spring wire, 0.177-in. diameter, tested Rockwell C-45 in hardness as received and withstood 346 alternate torsions to 180° before fracture. The same wire austempered by heating to 1560° F. and transformed for 20 min. in a salt bath at 660° F. had slightly greater hardness (C-46) and withstood 620 alternate torsions. The torsional endurance limit, as determined in conventional ways, was also raised about 15%.

We have obtained even more remarkable results after austempering patented spring wire of Italian manufacture. The following conclusion therefore appears to be logical, and based on our engineering research: That austempering steel spring wire will increase the number of alternate torsions to 180° a length of 50 diameters will endure before fracture, and also increase the fatigue limit in torsion, therefore will provide us with wire of distinctly superior quality for aero-engines.

ALBERTO OREFFICE

PERSONALS

Appointed district manager of the Chicago office of William Jessop & Sons, Inc.: **Thorvald L. Haines**, formerly with Columbia Tool Steel Co., Chicago. **The Bissett Steel Co.**, Cleveland, has been appointed northern Ohio, western New York and Pennsylvania agents for the sale of Jessop toolsteels.

Robert Wm. Knapp, graduate of Colorado School of Mines, has accepted a position with Aluminum Co. of America as fabrication metallurgist at the plant in Massena, N. Y.

Appointed assistant professor of metallurgy in the School of Mines, Columbia University: **Ettore Peretti**, who will take over the instruction in non-ferrous metallurgy formerly given by **Edward F. Kern**, who retires this year.

Local engineering service and warehouse stocks at principal industrial centers.

Fred L. Lawrence, formerly sales engineer for Pittsburgh Crucible Steel Co., has been appointed Detroit district manager for the Copperweld Steel Co. of Warren, Ohio.

Percy W. Fenner, formerly sales representative for the Firth-Sterling Steel Co., has been added to the sales personnel of Jessop Steel Co. in the Cleveland district. **W. H. Raisbeck**, formerly representative for Anderson Forge and Machine Co., has been appointed sales representative for Jessop in the Milwaukee district.

L. H. De Wald, formerly on the research staff of Vascoloy-Ramet Corp., North Chicago, Ill., is now sales metallurgist for Fansteel Metallurgical Corp. in the Cincinnati office.

Howard A. Smith, recently metallurgist for Rustless Iron & Steel Co., Baltimore, has been made chief metallurgist of the Duraloy Co., Scottdale, Pa.

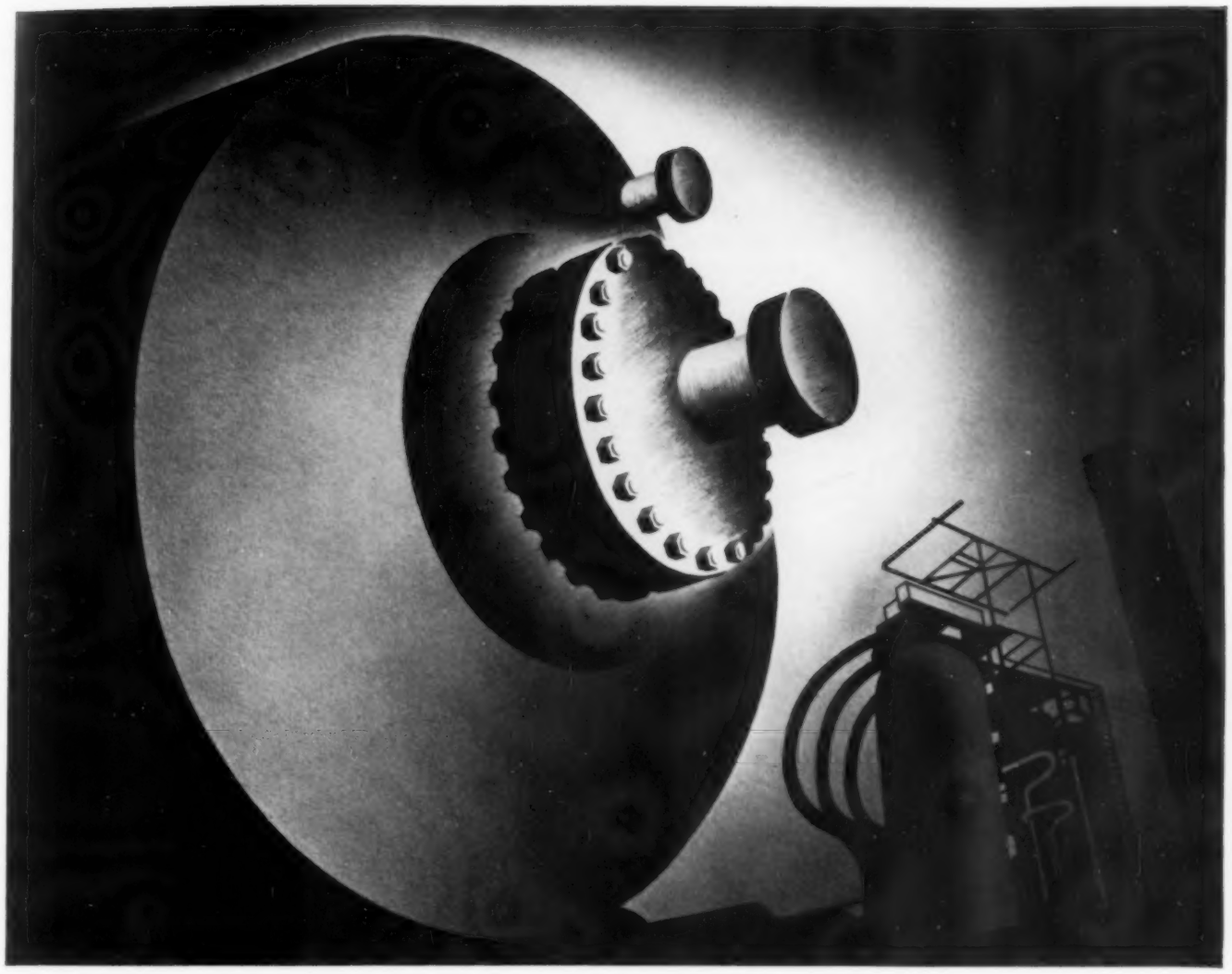
Sidney Isenberg, a recent metallurgical engineering graduate of Ohio State University, has joined the research staff of Battelle Memorial Institute.

C. S. Brainin has announced that the C. S. Brainin Division of I. Stern & Co., Inc., has moved to new and larger quarters in New York City.

J. F. Brendlinger is now associated with the United States Steel Export Co. in the merchandizing service of the sales department in New York City.

Wilton F. Melhorn has left the American Steel & Wire Co. in Joliet, Ill., to take a job in the drop forge shop of Bethlehem Steel Co., Bethlehem, Pa.

Among the new officers elected by the American Society for Testing Materials are the following, as members of the executive committee: **Paul D. Merica**, vice-president of International Nickel Co., and **Jerome Strauss**, vice-president of Vanadium Corp. of America.



HOLDING WHERE IT'S HOT

What with temperatures ranging up to 1000° F. and high stresses, the bolts used in much oil refinery equipment have no sinecure — and the failure of a single bolt may cause plenty of trouble.

That is why Chromium–Molybdenum (SAE 4140) steel is being more and more widely used for high temperature bolting on reaction chambers, pumps, etc.

This steel meets ASTM Specifications A 193-37 T. At the elevated temperatures encountered it has all the requisite physical properties, including good creep strength.

Chrome-Moly (SAE 4140) and other Molybdenum steels are meeting many of the special problems of refinery service with dependability and economy. These steels and their applications are described in our technical book, "Molybdenum in Steel". A copy will be sent free on request to any interested production executive or engineer.

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MOLY

PERSONALS

Transferred: Lt. **R. H. Lambert**, from instruction at Carnegie Institute of Technology to instruction at the Naval Gun Factory in Washington, D. C.

Paul D. Frost, graduate of Rensselaer Polytechnic Institute, is employed by Republic Steel Corp. at the Buffalo Plant.

F. X. Bradley, Jr. has completed the course of training at the Air Corps Training Center, and is now an instructor at the Air Corps Advanced Flying School, Kelly Field, Texas.

Joseph E. Foster has been re-employed by the U. S. Army Ordnance Dept. at the Rock Island Arsenal as junior metallurgist, after furthering his studies in metallurgy at the University of Illinois.

These jobs changed to SIL-FOS or EASY-FLO brazing because
. . . SIL-FOS and EASY-FLO offer many opportunities to improve joint quality at a reduction in cost that was not possible before these low temperature silver brazing alloys were developed.
With many, the change to SIL-FOS or EASY-FLO brazing was the outgrowth of cooperation between our brazing specialists and manufacturer's engineers.
If ferrous, non-ferrous or dissimilar metal joining is part of your production, find out what SIL-FOS or EASY-FLO can do for you. Write for full details, or ask to have a service engineer call at your plant and go over your metal joining operations.
. . . EASY-FLO speeded up production and greatly reduced rejects, as compared to the high temperature alloy formerly used to braze this
REFRIGERATION VALVE
. . . Replacing a casting, SIL-FOS brazing cut costs, reduced weight, made a far better looking finished part of this
SLIDING BRACKET
. . . EASY-FLO brazing in place of soft solders gave higher strength and reliability under high operating temperatures to joints in this
AUTO ENGINE OIL FLOAT
. . . EASY-FLO ended trouble with leaking joints, saved time and expense in brazing three different metals (steel, copper, brass) in this
REFRIGERATION ASSEMBLY
. . . EASY-FLO brazing replaced welding, gave high strength, neat joints and eliminated finishing expense in mounting these
CONDENSER STUDS
. . . SIL-FOS brazing in place of clamped joints saved metal, increased electrical efficiency, eliminated joint maintenance in this
BUS BAR SYSTEM
Always use HANDY FLUX with SIL-FOS and EASY-FLO. It's the only way to get the full benefit of the low working temperatures of these alloys.
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Melville Lowe, for the last ten years metallurgist at The Hevi Duty Electric Co., has established a metallurgical consultant service in connection with the Anderson Laboratories in Milwaukee.

D. C. Fabel has returned to Fenn College, Cleveland, as head of the department of mechanical engineering, after a year's leave of absence for graduate study in the engineering school at Yale University.

James A. Frank, graduate of Cornell University with an engineering degree, is employed by the Copperweld Steel Co. at the Glassport, Pa., wire division.

John J. Barnhardt, Jr., student in chemical engineering at Cornell University, will work during the summer vacation in the analytical laboratory of the Cannon Mills Co.

Appointed by Allegheny Ludlum Steel Corp.: **C. R. Mitchell, Jr.,** to assistant district manager of sales for the New York district office; **Deane Murphy,** to eastern manager of flat rolled carbon steel sales with headquarters at the New York office.

E. H. Anchors, formerly branch manager for the Air Reduction Sales Co. at Atlanta, Ga., has been appointed manager of the Oklahoma City district. **C. R. Hale** has been appointed purchasing agent of the Air Reduction Co., succeeding **H. M. Daggett,** who has retired.

Alex L. Feild, consulting metallurgist and director of chemical research, Rustless Iron and Steel Corp., and vice-president of Alloy Research Corp., was the recipient of one of the Modern Pioneer Awards of the National Association of Manufacturers.

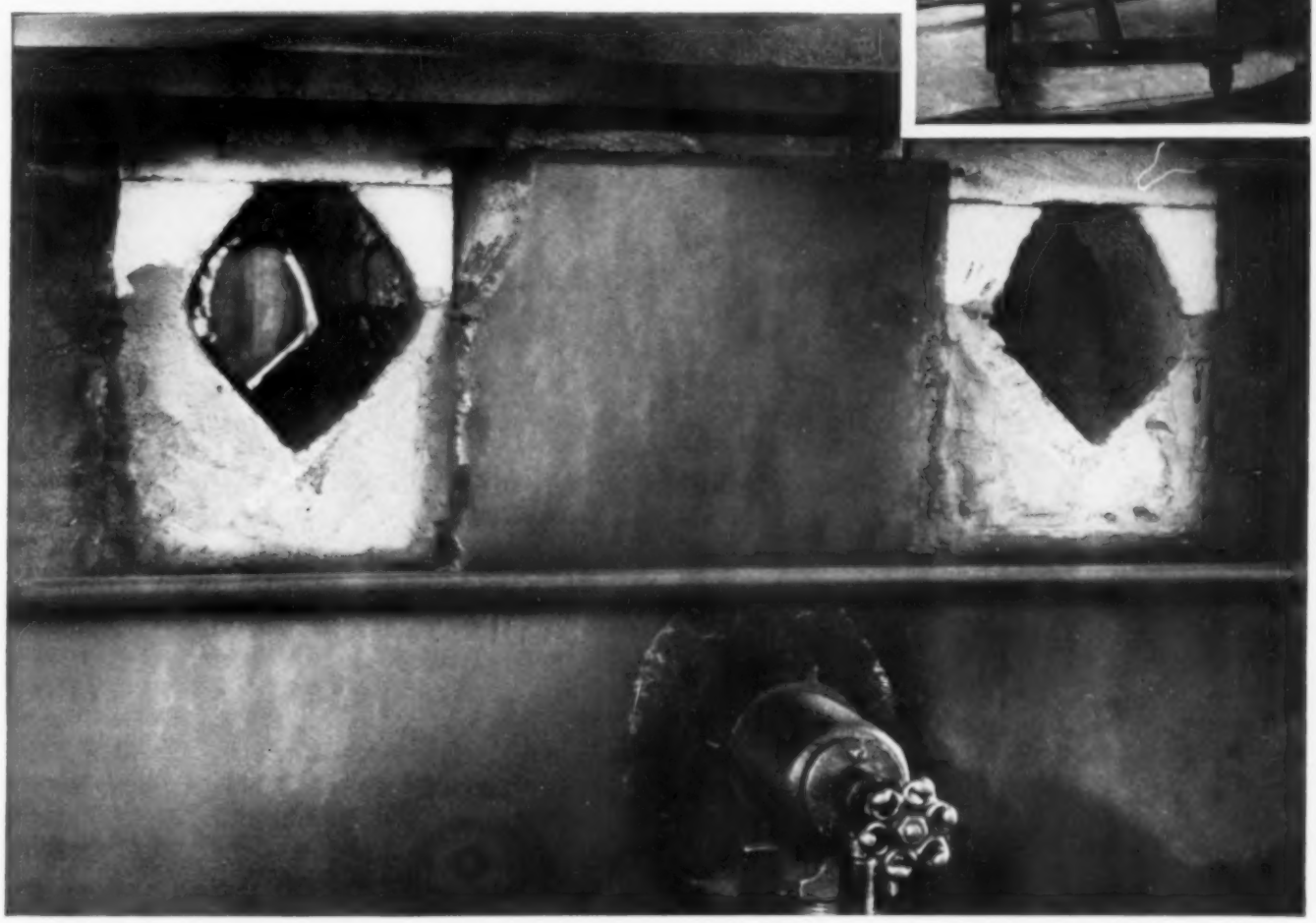
Transferred: **Lester R. Walker**, from the Lorain Division of Carnegie-Illinois Steel Corp. in Johnstown, Pa., to the Edgar Thomson Works at Braddock, Pa.

Here's proof

THAT "CARBOFRAX" RESISTS ABRASION

REG. U. S. PAT. OFF.

EVEN AT HIGH TEMPERATURES



• We talk so much about the high heat conductivity of "Carbofrax" hearths that the other desirable properties of this refractory are apt to be overlooked. • Here is a typical example of the use of "Carbofrax" where the primary reason for its use is to resist abrasion at high temperatures. The furnace illustrated is for heating large socket wrenches before a broaching operation. The wrenches slide through the furnace in the troughs. • Before "Carbofrax" was used, no method of construction would give a trough life of greater than 130 pieces. The furnace then had to be shut down for repairs. The pictures of the "Carbofrax" troughs were taken after 530 pieces had been run through and there is no sign of wear. The customer says "These troughs will last forever". • Perhaps not forever but it will be a long time before they are worn out. • Whatever your problem in maintaining heat treating furnaces, you should investigate "Carbofrax", the Carborundum Brand Silicon Carbide Refractory.

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PROGRESS IN ELECTRO-GALVANIZING

By J. A. Singmaster

Extracts from an address to the American Zinc Institute, April 30, 1940

TWO PAPERS read before the American Zinc Institute covered broadly the two methods of electro-galvanizing then in operation, and the division so made is still a logical one.

The Meaker process, described by ERNEST H. LYONS in 1938 is the older of the two, insofar as it describes the plating of iron or steel articles in a zinc sulphate bath, using metallic zinc as a soluble anode and the objects to be plated as the cathode. The anodes are cast in a wide variety of shapes, usually from high grade zinc; 99.99% is preferred even to zinc analyzing 99.985%. The impurities in lower grades cause the accumulation of sludge, which in turn interferes with the appearance of the work, disturbs the plating operation itself, and reduces the efficiency.

Anodes of metallic zinc become coated with sludge, which brings about the accumulation of decomposed zinc in the bottom of the plating tank. In order to overcome this difficulty, which takes place even with high purity zinc anodes to some degree, alloy anodes containing aluminum, mercury, or aluminum and mercury, have been proposed and their consumption has more than tripled in the past six years. Their claims may be summarized as follows:

1. Insolubility of the zinc except when the current is on.
2. Marked reduction of scrap.
3. Maintenance of the desired pH value of the solution.
4. Metal content of the solution can always be kept at the most advantageous point.
5. Prevents loss of zinc in sludge.

This Meaker process of galvanizing is used for a great variety of purposes. The largest tonnage of zinc is probably used in the electro-galvanizing of wire, including wire screen cloth, strip and conduit — where the operations are continuous. Other applications include pipe and conduit fittings, fasteners, automobile and wash machine parts.

There is a relatively new development employing metallic anodes, namely, the "coronizing" treatment. This deposits nickel on the steel articles, followed by electro-galvanizing; articles thus coated are then heat treated. This material has a high resistance to corrosion in the special applications thus far made. It is a development which is certainly worth following.

The estimated consumption

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THE handling of corrosive liquids — the pumping of acid sludge, mine waters and other abrasive bearing liquids can work severe havoc with the "innards" of pumps.

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of metallic zinc in the shape of anodes for electro-galvanizing was 4,000 tons for 1937 and 3,000 tons for 1938. Final figures are not available for the year 1939, but are estimated to be in excess of 5,000 tons — which shows a healthy growth in this method of galvanizing.

We now come to the second method of electro-galvanizing, namely, that described by J. C. TAINTON in his paper of 1937. The Bethlehem Steel Co. is the sole producer in this country of material electro-galvanized by this process, called by them "bethanizing", in departments in the Sparrows Point plant (started in 1933) and since 1935 in a similar unit of larger capacity at the Johnstown plant. The latter was described in METAL PROGRESS in May 1937. The product from this unit goes largely into fencing for farm use, replacing the hot-dip wire previously used. The combined output of the two plants is of the order of 180 tons of wire per day.

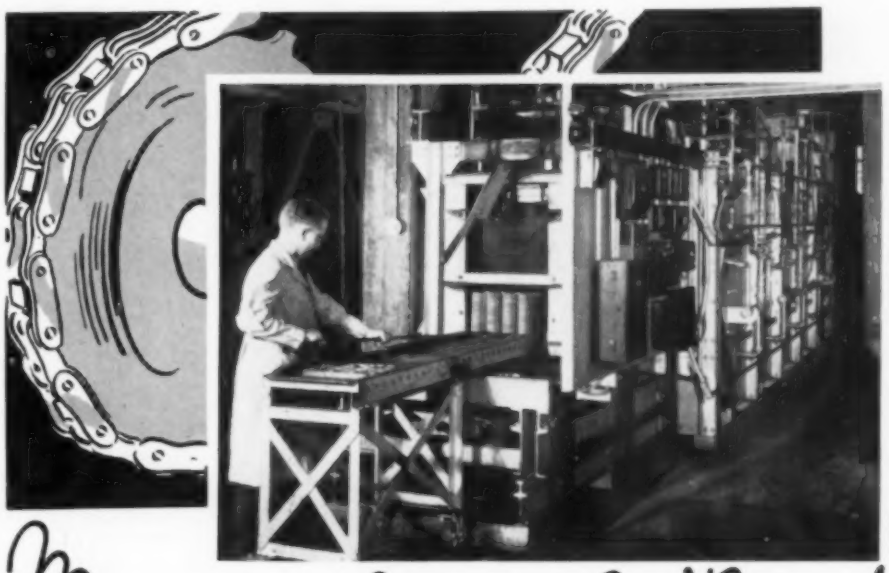
The commercial success of this development is reflected in the Bethlehem company's Annual Report to Employees for 1939, which notes the bethanizing process as an important recent development for increasing the utility of zinc-coated wire, and says that bethanized sheets are now being made in a pilot plant.

Many of the operations in the Tainton process (bethanizing) parallel those in the manufacture of electrolytic zinc from the ore. It uses an insoluble anode and supplies the zinc to the bath in the form of a purified zinc sulphate solution, which in turn is obtained by dissolving zinc directly from roasted zinc ore. In the cell a strongly acid condition is maintained and as zinc is deposited additional free sulphuric acid is generated in the solution which is circulated through the bath and leaves it in condition to dissolve more zinc. After suitable enrichment and purification it is again returned to the bath for the deposit of more zinc.

It is evident that this method eliminates the necessity of making spelter from the ore, and consequently has on its credit side the cost of smelting the zinc. It also has on its credit side, insofar as the actual commercial plants we know of are concerned, the advantage of using a much higher current density, — approximately 1,000 amp. per sq.ft. of cathode surface against 400 to 500 in the process using metallic zinc anodes.

On the debit side is the purification of the solutions, which requires close supervision and some expense. Minute quantities of various impurities can interfere very seriously with efficiency of deposition. In our opinion the credits for this process so far outweigh the debits

(Continued on page 80)



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Trays carrying work are pushed through furnace by Hydraulic Pusher; Hydraulic Lowerator, Transfer and Elevator Automatically carry trays through Quench.

There are three control zones automatically holding carburizing temperature at 1700 F.

If you have a furnace problem, let a Holcroft engineer make a recommendation at no obligation. Write today for the Holcroft booklet "Controlled Atmospheres".

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This is NEWS!
Volume I—No. 6
New York, N. Y., April 26, 1940
NATIONAL METAL EXPOSITION SPACE OVER-SUBSCRIBED SEVEN MONTHS IN ADVANCE OF OPENING OCTOBER 21
Y. WORLD'S FAIR
Private Buildings Erected by 38 Companies At Tulsa Show
A M A Will Use Four Floors at N. Y. Meet
NEW YORK, April 26—The Scientific and Technical Exhibits of the American Medical Association will be held at Grand Central Palace here June 10 to 14 during the convention. The usual number of exhibitors—about 300—are expected. Four floors of the building will be used for displays.
HEAVY DEMAND FOR METAL SHOW SPACE MORE TO BE ADDED
Over 86,000 Square Feet Reserved—More Space Than Used in 1939
CLEVELAND, April 26—An unexpected heavy demand by exhibitors in previous shows for floor space in the 1940 National Metal Exposition has made necessary the laying out of a new plan which will have several thousand additional square feet of floor space. This action was decided on by the space assignment committee after reservations were received for over 86,000 square feet of space, more than was provided for on the original plan. Although the show will not be held until the week of October 21, advance space reservations are now far in excess of any pre-

...NEWS THAT MEANS MORE SALES FOR METAL EXPOSITION EXHIBITORS

When this story broke in the newspapers, metal men forgot political news for a while—forgot World War No. 2—and started to speculate about this biggest National Metal Exposition which will open in October at Cleveland.

If this is the biggest Metal Exposition in 22 years, they said, we'd better be there to get our share of the business. Because last year 33,000 of our best prospects attended the Metal Exposition.

And so . . . to the Metal Exposition headquarters in Cleveland . . . have come letters, wires and telephone calls by the dozens. Reserving spaces for big and little companies who sell the metal industry everything from pyrometers to tons of steel.

But there are still plenty of good spaces left at the regular $1.00 a square foot rate because Cleveland's ample Public Auditorium provides more than 150,000 square feet for the Metal Exposition.

So write or wire collect today for full particulars. Address: W. H. Eisenman, Director, National Metal Exposition, 7301 Euclid Avenue, Cleveland, Ohio.

The WORLD'S GREATEST EVENT IN THE METAL INDUSTRY 70% NEW ATTENDANCE EACH YEAR

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Wire Association
American Welding Society
Iron & Steel Division and Institute of Metals Division of the American Institute of Mining & Metallurgical Engineers

NATIONAL METAL EXPOSITION

AND METAL CONGRESS

OCTOBER 21-25, 1940 *Cleveland, Ohio*

MANAGED BY AMERICAN SOCIETY FOR METALS

Only
ALLOY STEELS
provide all these advantages

Despite the improvements in fine carbon steels, such steels are limited in application—leaving a wide field where only alloy steels are truly economic. When machine design limits the size of a part—when high strength must be combined with light weight—when surface hardness and ductility must be held within close limits on production parts—then alloying elements are important—to produce a steel to do a definite task—to do more work with certainty of results at lower cost.

When sections are large—when hardness must be carried deep into the steel—as in shafting, heavy crankshafts and piston rods, large gears, axles and heavy connecting rods—alloy steels are necessary and the cost low in proportion to results. In such parts, with carbon held constant, the depth-hardening quality increases as the alloy content is increased.

• • •

When weight and space limitations demand that smaller sections carry heavier loads—safely—the answer must be alloy steels. Under repeated stress, tensile strength and hardness do not necessarily indicate fatigue properties. Rather, the load-carrying ability of a steel depends upon the alloy constituents and the form of the structure at the time it is bearing the load.

• • •

When steel parts and equipment must withstand high pressures and elevated temperatures, no ordinary steel is suitable. This is exclusively a field for alloy steels—steels that have proved their high resistance to creep—steels that maintain high strength up to 1800°F.—steels that resist oxidation and therefore do not lose their strength appreciably through reduction of section.

Where steels of high elastic properties and strength are needed, and especially where weight reduction is important, low carbon complex alloy steels properly welded offer distinct advantages. Such alloy steels at equal or higher yield points show lower weld hardening, improved resistance to corrosion, improved ductility of weld, better retention of toughness at sub-zero temperatures and better creep resistance at high temperatures.

• • •

Republic—world's largest producer of alloy steels—will be glad to recommend the correct steel for any specific use. Write Republic Steel Corporation, Alloy Steel Division, Massillon, Ohio; General Offices, Cleveland, Ohio.

REPUBLIC STEEL

BERGER MANUFACTURING DIVISION
NILES STEEL PRODUCTS DIVISION
STEEL AND TUBES DIVISION
UNION DRAWN STEEL DIVISION
TRUSCON STEEL COMPANY

Republic Alloy Steels

AN ECONOMIC NECESSITY IN THE MANUFACTURE OF INDUSTRIAL EQUIPMENT

Electro-Galvanizing

(Starts on page 76)

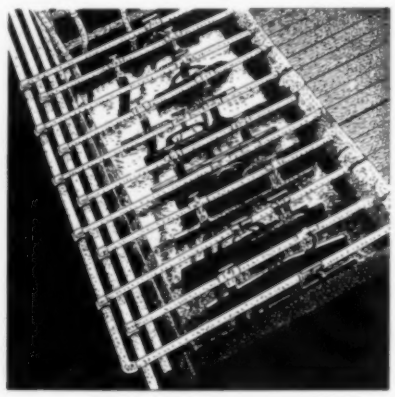
that a vastly increased use of zinc dissolved directly from ore for galvanizing is indicated. The over-all recovery of zinc from the ore to the galvanized object is very high.

While this process has found no commercial application outside of the Bethlehem Steel Co. in this country, at least two and probably more plants are using the process in Europe. In England there are two plants, one of them galvanizing wire for aircraft, a service which imposes very rigid specifications, since the wire has to be of the maximum tensile strength. The other plant, according to our information, is galvanizing the very heavy wire or rods used in the manufacture of submarine nets.

A second process utilizing zinc ore or zinc by-products directly with insoluble anode has been patented by HUBBELL and WEISBERG. It uses ammonia and ammonium salts as the solvent, and operates as well or indeed better in a chloride electrolyte, and accordingly makes available high chloride materials, such as sal skimmings. Plating therefore takes place in alkaline instead of acid solution. The extraction of zinc from ordinary roasted ore, Waelz oxide and zinc by-products is generally quite high.

Purification of the alkaline solution is a much simpler matter than in the Tainton process, since many of the harmful impurities do not go into solution and others (notably chlorine) which interfere with the deposition from sulphate have no effect. High current densities of the same range are used with excellent results. Hundreds of small runs have been made on various sizes and kinds of wire. Upwards of 100 tons of strip steel 10 in. wide have been satisfactorily galvanized by this process in a pilot plant, and the surface has remarkable adherence for paint without any pre-treatment.

All of the methods under consideration are capable of producing adherent zinc coatings with good bending properties of any desired commercial thickness on wire and narrow strip. We have no doubt that wide strip and sheet commercially electro-galvanized will be on the market in commercial quantity in the near future.



One of Our Customers Writes

"The light-weight sheet welded pots which you sold us in 1928 were used continuously until 1932. They were back in service again last year and only now require replacement. We are taking this into consideration and are sending you our order for additional light-weight pots."

Manufacturers everywhere have been able to effect substantial savings through the use of our light-weight carburizing equipment. The best proof that our equipment is saving money in heat-treating operations is the fact that more than 80% of the carburizing boxes used in the U.S. are manufactured by us.

Send us your blue prints for quotation on present or future requirements.

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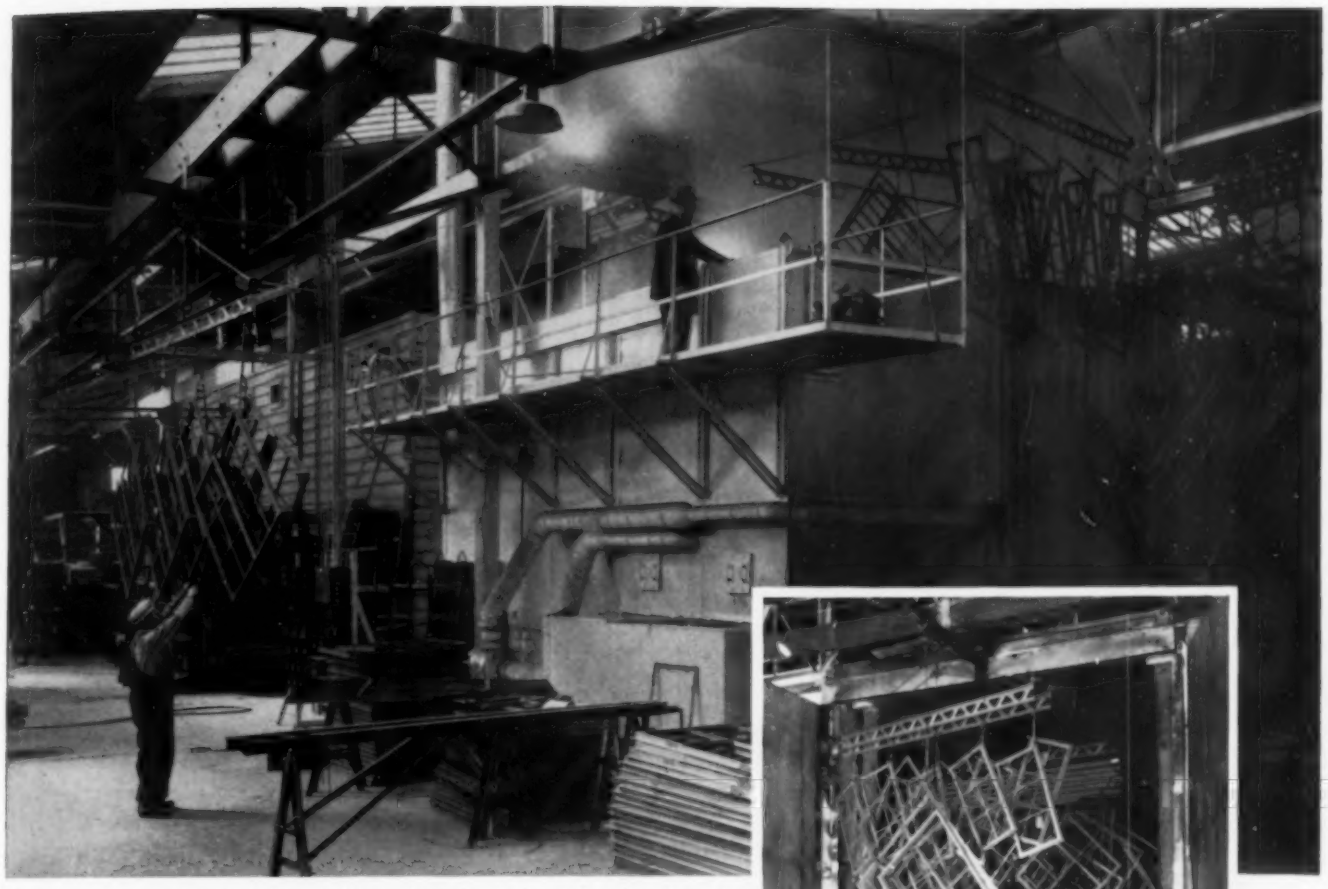
THE PRESSED STEEL COMPANY

WILKES-BARRE PENNSYLVANIA

Pressed Steel Company Products: CARBURIZING AND ANNEALING BOXES . . . THERMOCOUPLE PROTECTION TUBES . . . SEAMLESS STEEL CYLINDER CAPS . . . SEAMLESS STEEL NECK RINGS . . . SPECIAL ALLOY HEAT-TREATED BUBBLE CAPS . . . WELDED ALLOY TUBING for High Temperatures and Corrosive Application



Rust-proofing steel sash in bonderizing plant. Soule Steel Co., San Francisco.

"Only GAS Fuel Gives Necessary Thermal Efficiency" for Bonderizing Plant

When the Soule Steel Company of San Francisco built there the largest bonderizing plant in the West, for rust-proofing steel sash, it brought about a new victory for Gas fuel and modern Gas equipment. For new problems in heat application were readily solved with Gas fuel, automatically controlled. And in this unusual installation, Gas company engineers helped to obtain smooth efficiency and continuous operation—from the complicated six-tank bonderizing unit to the paint drying oven.

"Only Gas Fuel," says this company, "could give us the necessary self-contained mechanical and thermal efficiency. Quick, unvarying temperatures at such low cost are possible with no other fuels."

For hardening, annealing, tempering, normalizing, blueing, carburizing, forging, galvanizing, and many other industrial processes, Gas is the preferred fuel—preferred because it is quick heating, clean, flexible, accurately controlled as to temperature and furnace atmosphere, and of all fuels highest in utilization value.

Whatever your heating requirements, your Gas company offers helpful advice. Why not find out what Gas and the latest Gas-fired equipment can do for you?

AMERICAN GAS ASSOCIATION

INDUSTRIAL GAS SECTION

420 LEXINGTON AVENUE, NEW YORK CITY

POT FURNACES

Gas Fired

THESE DETAILS INSURE GOOD PERFORMANCE . . .

THE CONTAINER
Pressed steel . . . insuring long life, consistent service. Thin section gives rapid heat conduction.

BURNERS
McKee Burners used in conjunction with properly designed, preburned combustion blocks insure satisfactory operation.

BOTTOM
Heavy top and bottom castings are of cast iron. Expansion ring on top casting eliminates infiltration of lead or salts into furnace combustion chamber.

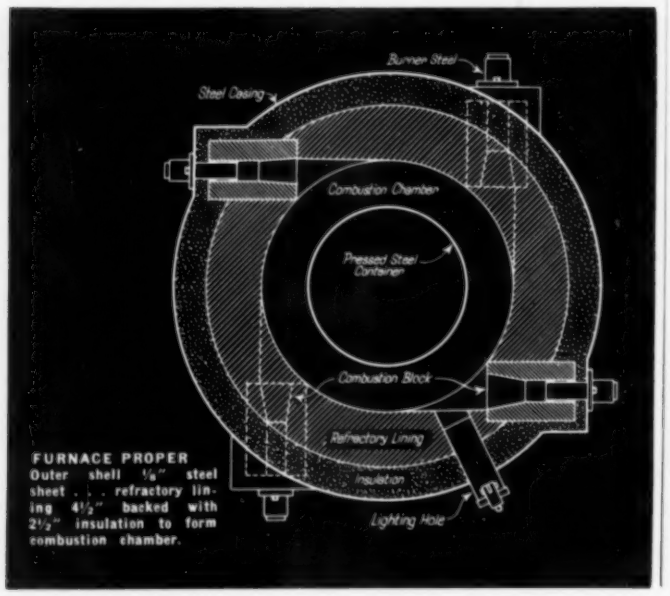
FLUE BOX
Old style cast iron flue has been replaced with refractory lined flue box.

McKee Control Valve and Pressure Blowers are Available in a Wide Range of Sizes for Use with Eclipse Furnaces. McKee Proportional Mixers, Standard on all Furnaces, Insure Proper Furnace Atmosphere and Maximum Fuel Economy.

ECLIPSE FUEL ENGINEERING CO.

Manufacturers of All Types of Industrial Fuel Equipment

ROCKFORD -:- ILLINOIS



FURNACE PROPER
Outer shell 1/8" steel sheet . . . refractory lining 4½" backed with 2½" insulation to form combustion chamber.

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Announcing
ATMODIE
air hardening, non-deforming die steel of superior quality.

Useful hardness with toughness is developed using air quench.

It pays to use Good Tool Steel.

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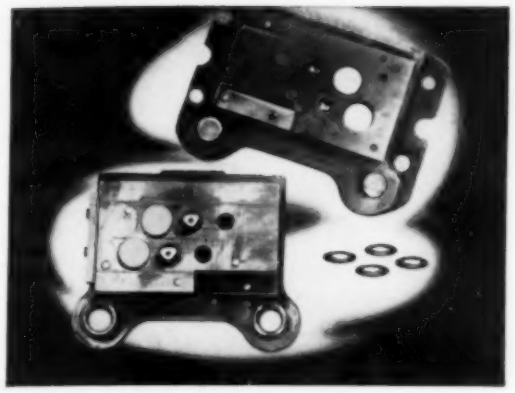
"SHUTDOWN PROBLEM"



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64 More Hours For Production Per Month
460,000 More Pieces Per Month

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4 More Hours For Production Per Month
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THE CARPENTER STEEL COMPANY
READING, PA.

ANSWERING FIVE COMMON QUESTIONS ON "TOOL-CAUSED SHUTDOWNS"

IN THE AVERAGE PLANT, HOW MANY HOURS AND HOW MUCH OUTPUT CAN BE GAINED BY REDUCING TOOL-CAUSED SHUTDOWNS?

These tools show typical gains—ranging from several hours to a week or more in a 200 working hour month . . . from a few thousand pieces extra output to nearly half a million per month. These figures are not tool life but extra hours for production and extra output per machine gained each month by improving tool performance.

HOW CAN I SPOT TOOLS CAUSING UNNECESSARY SHUTDOWNS IN MY PLANT?

You can do it by judging tool performance on the basis of the Good Tool Formula — described and illustrated in Carpenter's new booklet on hidden plant capacity (see coupon below). Experience shows that the biggest troublemakers are often tools that seem to be O.K. but which can be vastly improved by the use of tool steels better suited to the job.

ONCE SUB-PERFORMANCE TOOLS HAVE BEEN SPOTTED, IS IT EASY TO REDUCE TOOL-CAUSED SHUTDOWNS?

Yes — provided you have toolmaking experience and provided you use Carpenter's Matched Set Method of Tool Steel Selection. By combining the two, you can put your finger on the trouble at once. Then you simply follow the arrows on the Matched Set map to find the remedy.

HOW MUCH DOES IT COST TO INTRODUCE THE MATCHED SET METHOD INTO A PLANT?

Not an extra penny. In fact, by making the selection of the most economical tool steel easy, you actually can reduce the cost of your tooling as well as reducing shutdown time. Each step is taken in accordance with detailed instructions given in black and white.

WHAT IS THE FIRST STEP I SHOULD TAKE TO REDUCE TOOL-CAUSED SHUTDOWNS?

The first step is to mail the coupon below for a free copy of the new Carpenter booklet on "hidden plant capacity." It tells how the Matched Set Method operates to reduce plant shutdowns and suggests the easy, quick way to cash in.

THE CARPENTER STEEL COMPANY
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Gentlemen:
Without obligation, please send me my copy of your new booklet showing how to uncover extra output and lower unit costs in my plant.

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MATCHED
TOOL STEELS

Extreme ACCURACY

Minimize Distortion of Tools and Dies with JESSOP "TRUFORM" Oil-Hardening TOOL STEEL

One user reports the deformational variation of TRUFORM on quenching was only .004325" as compared to .00456" for the best steel previously used. Other desirable properties of TRUFORM include high wear resistance, increased toughness and wide hardenability range.

TRUFORM is but one of the many JESSOP TOOL STEELS which have won wide recognition for their dependability and superior performance. Write today for your free copy of the new chart of JESSOP TOOL STEEL RECOMMENDATIONS, showing recommended tool steels for over 150 types of tools. Please use your company letterhead.

Jessop Steel Co., 624 Green St., Washington, Pa.
ESTABLISHED 1901

Jessop Steels of America
CARBON- HIGH SPEED- SPECIAL ALLOY- STAINLESS- and COMPOSITE STEELS

Want to Reduce Annealing Costs?

KENNAMETAL Cuts Hardened STEEL Like a HOT KNIFE Cuts Butter

STYLE NO. 11 TOOL with Chip Breaker

Machinists like KENNAMETAL because it machines steel 2 to 6 times faster than high speed steel tools, removes 10 to 50 times more metal per tool grind and can take jump cuts without breakage.

Plant metallurgists like KENNAMETAL because it reduces fabricating costs all down the line. KENNAMETAL machines steel of all hardnesses up to 550 Brinell—often eliminating annealing operations—and the resulting finish is so smooth and accurate that it is usually unnecessary to grind or polish after machining.

If production costs form part of your responsibilities—investigate KENNAMETAL steel cutting tools without delay. Write for our new catalog describing 20 standard style KENNAMETAL-tipped tools for every operation.

McKENNA METALS Co.
156 LLOYD AVENUE
LATROBE, PENNSYLVANIA, U.S.A.

SORBY'S PIONEERING

(Starts on page 45) *Transactions*, although its contents were included in the comprehensive paper given later (1887).

It may be interesting to summarize what SORBY had discovered regarding the structure of steel during his work in the early sixties. He had demonstrated the presence of one metallographic constituent which was evidently iron in a state approaching purity, of another which was a hard compound of iron and carbon, and of another which was graphite. He had also noticed the constituent which was recognisable by its pearly luster. If one compares this with the structural descriptions given in WEDDING's paper in 1885, one can see how much further SORBY had progressed even by 1864.

Interest in metallography being newly awakened, SORBY again gave his attention to the subject and in 1885 took the important step of using high magnifications in his examination of iron and steel. Previously he had found that the use of 200 diameters had revealed little, if any, more than could be seen at 50 or 60 diameters and ease of working led him to use the latter power. In 1885, however, he used a magnification of 650 diameters, employing the now familiar Beck illuminator which, he remarked, enabled him to obtain an illumination at these high powers as good as, if not better than, that he had previously had with low powers. A new order of structure now became visible, the pearly constituent which he had previously described was now seen to be composed of alternate layers of a hard and a soft constituent, its resemblance to mother-of-pearl being thus due to a real similarity of structure. Careful observation convinced him that these thin plates consisted on the one hand of iron free from carbon and, on the other hand, of the intensely hard substance he had seen so often in blister steel. He also found that, when strongly heated, these alternating plates combined and, when suddenly chilled again, "there is no evidence that they separate though it is possible that this may be because the particles are too small to be separately defined".

This brief paper on high magnifications, published in 1886 (reprinted in METAL PROGRESS last July), appears to have attracted considerable attention among members of the Iron and Steel Institute and as a *(Continued on p. 106)*

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Heating operations in the ceramic field have many points in common with the heat treating field. For one thing, many of the equipment manufacturers that have developed modern heat treating equipment also furnish equipment for lehrs, kilns, enamel ovens and miscellaneous heating units.

In common with heat treating, a smooth continuous flow of clean dry air is essential for close control and perfect timing.

Also, as in heat treating, the majority of equipment manufacturers in the ceramic field prefer and recommend Spencer Turbo-Compressors.

If it's a job that needs plenty of air at low pressures,

ASK YOUR EQUIPMENT MANUFACTURER

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SPENCER HARTFORD **TURBO COMPRESSORS**

35 TO 20,000 CU. FT. ⅓ TO 300 H.P. 8 OZ. TO 5 LBS.

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Metal Blackout

The new JETAL process for blackening iron and steel quickly and thoroughly at low cost is described in literature available through the Alrose Chemical Co. Bulletin Cd-256.

Conjecto-Firing

A wider temperature range and closer control, known as Conjecto-Firing, is now available in Surface Combustion furnaces. A four-page leaflet describes the advantages of this system. Bulletin Ed-51.

Aluminum Finishes

A new booklet which lists the finishes available for various forms of Alcoa Aluminum Alloys has just been released from the press by the Aluminum Company of America. Bulletin Ed-54.

New X-Ray Unit

A new X-ray diffraction unit, smaller and more versatile than previously available outfits of this type, is described in a comprehensive folder released by the General Electric X-Ray Corp. Bulletin Hc-6.

Tocco Process

The marvel of all heat treaters—the Tocco Process of Induction Hardening—is fully described in a colorful folder by the Ohio Crankshaft Co. Bulletin Lc-145.

Die Blocks

A handy, small size spiral-bound leather notebook is a complete handbook on Heppenstall Company's die blocks. Valuable additional data are contained, as well as a few blank pages for memoranda. Bulletin Ca-122.

Stainless Data Book

All users of stainless and heat resisting alloys should find invaluable the information contained in a booklet published by Maurath, Inc., giving complete analyses of the alloys produced by the different manufacturers, along with the proper electrodes for welding each of them. Bulletin Jy-125.

Inconel

The properties and uses of "Inconel," a corrosion-resisting alloy of approximate composition 79.5% Ni, 13% Cr, and 6.5% Fe are discussed in a valuable technical bulletin made available by the International Nickel Co., Inc. Bulletin Cc-45.

Chapmanizing

Chapmanizing, the method of surface hardening steel with nitrogen, is described in a very attractive booklet of Chapman Valve Mfg. Co. Information is given on the method itself and on its metallurgical advantages. Bulletin Ob-80.

Potentiometer Controllers

A new 24-page illustrated bulletin issued by the Foxboro Company completely describes appearance and action of their large line of controllers. Bulletin Cc-21.

Lectrodryer

A machine designed specifically for the dehumidification of air and other gases as well as certain liquids—the "Lectrodryer"—is pictured and explained in a booklet by the Pittsburgh Lectrodryer Corp. Bulletin Gc-187.

Rotoblast

Several unusual features make the Pangborn Rotoblast of more than ordinary interest to manufacturers with a metal cleaning problem. Described in booklet by the Pangborn Corp. Bulletin Ed-68.

Park-Kase

A leaflet by Park Chemical Co. contains complete information concerning a new liquid carburizer of rapid and uniform penetration. Unique features and advantages of the bath are backed up with technical data. Bulletin Na-141.

Electric Furnaces

A new catalog on electric furnaces and pyrometers has been released by the Hoskins Manufacturing Company. For anyone who does any kind of heat-treating, brazing, or uses heat-resisting castings. Bulletin Hc-24.

Modern Analysis

A 24-page booklet just released by the Harry W. Dietert Co. will help you get accurate analysis in minutes instead of hours. Chemical analysis forms a very important link in modern production and this booklet gives you practical ways of obtaining quick, accurate results. Bulletin Gb-198.

USE THE COUPON ON PAGE 94 TO OBTAIN THIS HELPFUL LITERATURE

Crucible Furnaces

A new bulletin on multiple unit crucible furnaces and Hevi Duty crucible furnaces has been released by the Hevi Duty Electric Co. Bulletin Hc-44.

Moisture Determination

A very colorful leaflet by the Harry W. Dietert Co. describes new, rapid methods of determining moisture content by drying. Illustrated. Bulletin Cd-198.

Clean Hardening

Continuous clean hardening machines for work ranging from extremely small, light springs, stamping, drop forgings, etc., up to quite large and heavy pieces are described in a bulletin by the American Gas Furnace Co. Bulletin Ed-11.

Vanadium Steel

Latrobe Electrite Vanadium High Speed Tool Steel is described in literature released by the Latrobe Electric Steel Co. Bulletin Kb-208.

Industrial Furnaces

Furnaces of all types are fully described in technical bulletins made available by the Eclipse Fuel Engineering Co. Bulletin Ec-226.

Industrial Furnaces

A series of interesting bulletins showing Dempsey Industrial Furnaces in a wide range of requirements is now available through the Dempsey Industrial Furnace Corp. Bulletin Dd-260.

Electric Furnaces

Holcroft & Co. have a 30-page booklet which tells the story of a score of representative furnace installations, giving production records, operating data and furnace description. Bulletin Kb-203.

Microscope Accessories

A 62-page catalog with index and price list describes and illustrates all sorts of microscope accessories, including a wide variety of objectives and eye pieces, made by Bausch & Lomb Co. Bulletin Sx-35.

Heat-Corrosion Resisting

A handsome new 56-page book on electrical heat and corrosion resisting alloys containing general information and useful data about such alloys has just been published by the Driver-Harris Co. Bulletin Cd-19.

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Ingot Production

"The Ingot Phase of Steel Production" is the title of a book defining the principles of quality ingot production followed by many well-known steel manufacturers. Gathmann Engineering Co. Bulletin Ka-13.

Brazing Silver Alloys

A new and colorful folder just released by Handy & Harman is full of interesting pictures showing how metals can be joined with better, more economical results with SIL-FOS and EASY-FLO. Bulletin Fd-126.

Off the Payroll

"Deadweight is off the payroll with U.S.S. High Tensile Steels" is the title of a new folder issued by U.S. Steel. Contains not only technical information which is of particular interest to engineers but additional information of general interest. Bulletin Ib-79.

Tool Steel Guide

A 36-page booklet which gives a clear picture of the entire range of tool steels and their fields of use, plus a systematic method for selecting the right steel for the purpose, is being released by Bethlehem Steel Co. Bulletin Bc-76.

Carburizing Salt

A technical service bulletin describing a new development — Du Pont Carburizing Salt — for the economical production of deep high-carbon cases on plain carbon and alloy carburizing steels . . . available through Du Pont. Bulletin Dc-29.

Heroult Furnace

Revised and expanded to include modern major innovations in the construction and operation of the Heroult electric furnace, the latest edition of the American Bridge Co.'s Heroult Electric Furnace Bulletin is available. Bulletin Bb-124.

Metal Heating

Improvements in furnace economies, operating conditions and appearance, furnaces that will more satisfactorily meet old requirements or handle new processes, service that will help solve the most stubborn problems are offered and described by Mahr Mfg. Co. in Bulletin Ea-5.

No Decarburization

A low cost method of hardening and annealing under production conditions with no decarburization is described in technical data available through Westinghouse Electric & Mfg. Co. Bulletin Fd-134.

Colmonoy

The high resistance to wear and corrosion which distinguishes Colmonoy alloys and overlay metals is explained in a 4-page catalog released by Wall-Colmonoy Corp. Bulletin Bc-85.

Seamless Tubes

Prepared by the Timken Steel and Tube Division of Timken Roller Bearing Co. is a "Guide for Users of High Temperature Steels" which presents technical data relating to the various properties of Timken seamless tubes. Bulletin Bb-71.

Heat Resisting Alloys

Authoritative information on alloy castings, especially the chromium-nickel and straight chromium alloys manufactured by General Alloys Co. to resist corrosion and high temperatures, is contained in Bulletin D-17.

Mounted Wheel Chart

A convenient ready reference wall chart showing mounted grinding wheels should be of great advantage in the cleaning room, pattern shop, tool and die room, and many other places. It gives at a glance, by means of detailed drawings, actual size, the exact radius of each wheel and its exact shape. Chicago Wheel & Mfg. Co. Bulletin Bd-230.

Heat Treating Hints

A helpful, colorful booklet edited by experienced heat treaters is available through the Lindberg Engineering Co. Bulletin Bd-66.

High Speed Steel

Required hardness and extraordinary toughness combine to make Firth-Sterling Co. new high speed steel "Mo-Chip" of unusual interest to manufacturers who need a steel that is "practically indestructible." Bulletin Ad-177.

USE THE COUPON ON PAGE 94 TO OBTAIN THIS HELPFUL LITERATURE

Oil Burners

North American Mfg. Co. offers a bulletin describing improved low pressure oil burners, one type especially designed for automatic control and ideally suited for use with proportioning control valves. Bulletin Na-138.

Metallographic Equipment

The 100-page "Metal Analyst" issued by Adolph I. Buehler features new Metallographic Sample Preparation Equipment; a comparative listing of Metal Microscopes, Measuring Microscopes, and Spectrographs; an index of over 1,000 new technical books and papers; and a treatise on the Application of Reflected Light. Bulletin Ed-135.

Lubrication

Intensive research which completed important improvements in the field of heavy-duty gear and bearing lubrication is tabulated in a new 12-page illustrated bulletin released by D. A. Stuart Oil Co., Ltd. Bulletin Lb-118.

Oil Burners

A new model proportioning oil burner giving accurate combustion and temperature control with greater fuel economy is described in a booklet by the Hauck Manufacturing Co. Bulletin Ed-181.

Bright Annealing

Various types of electric and fuel-fired furnaces built by the Electric Furnace Co. for bright-annealing wire, tubing, strip and other products are described in an 8-page folder. Bulletin Lb-30.

Ferrocarbo

A cupola addition, "Ferrocarbo", which improves casting quality, lowers costs and reduces rejects is described in literature available through the Carborundum Co. Bulletin Bd-57.

Annual Index

The Annual Index of the Copper Alloy Bulletin published regularly by the Bridgeport Brass Company is now made available through this company. Bulletin Kc-163.

Foundry Sand

A pamphlet recently issued on TAM Foundry Zircon Sand and TAM Zircon Flour contains detailed information on these products of the Titanium Alloy Mfg. Co. Bulletin Hc-90.

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THE PROGRAM
FOR NATIONAL
DEFENSE . . . .

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Heat Treating Salts . . . . Carburizers . . . . Rust Preventatives . . . . Core Oils . . . . Cutting Oils . . . . Drawing Compounds . . . . Metal Cleaners . . . . Lubricants

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Hardening Furnace

A new pamphlet which describes "Certain Curtain" furnaces made by C. I. Hayes, Inc., will be particularly interesting to those with hardening problems. Bulletin Nc-15.

Tool Care

A new catalog on Kennametal tools for machining steel and other metals is valuable to anyone interested in better machining results. McKenna Metals Co. Bulletin Ed-238.

Welding Stainless Steels

A 24-page technical bulletin, giving important information for the engineer, designer or welding operator on the welding of stainless steel, is available through the Arcos Corp. Bulletin Hc-191.

Portable Electric Furnace

A unique portable electric furnace designed for use at temperatures below 1100° F. with drawing salts and oil tempering baths is described in a booklet by Claud S. Gordon Co. Bulletin Ed-53.

New Electric Furnace

An electric furnace that is new in every respect . . . including new insulating refractory lining, increased wall insulation, simplified door lift mechanism . . . is described in a bulletin released by the American Electric Furnace Co. Bulletin Gd-2.

Specialty Steels

The large stocks of High Speed, Tool, Stainless, Alloy, Production and Special Purpose Steels carried by the Crucible Steel Company of America are listed in a Stockbook which is now available. Bulletin Gd-56.

Special Alloys

If you have a corrosion, high temperature, or abrasive problem, you will be interested in the new booklet which covers special alloys manufactured by the Duraloy Co. Bulletin Gd-233.

Anti-Scaling Compound

An oxide armor for steel parts exposed to high heat which triples the life of the steel is described in an interesting illustrated booklet released by E. F. Houghton & Co. Bulletin Gd-38.

Blast Furnace

Feature of a 20-page new booklet issued by Leeds & Northrup Co. covering a complete line of temperature measuring and controlling equipment for the blast furnace is a big two-page diagram of a typical blast furnace on which are shown all important points at which temperatures are detected. Bulletin Gd-46.

Stainless Steels

A 28-page booklet general in nature and describing the properties and applications of Republic Enduro Stainless and Heat-Resisting Steels is now available through the Republic Steel Co. Bulletin Gd-8.

Thermocouples

The complete line of Thermocouples, Thermocouple Wire, Lead Wire, Insulators, Protecting Tubes, etc., offered by Wheelco Instruments Co. is described in a new booklet. Bulletin Gd-110.

Extra Output

A new way to get more from your present production set-up is explained by the Carpenter Steel Company in their new booklet. Bulletin Gd-12.

Insulating Mix

A new insulating Concrete-Mix used to form rammed monolithic or cast shapes, simply by adding water, is described in a leaflet just issued by The Babcock & Wilcox Co. Bulletin Gd-75.

Typical Jobs

A helpful scrapbook of typical jobs done on the DOALL Contour Cutter, containing a collection of informative drawings, is available through Continental Machines, Inc. Bulletin Bd-170.

Die Steels

A high carbon, high chrome, oil hardening die steel especially suitable for blanking and forming dies, burnishing dies or rolls, plug gauges, drawing dies for bars or wire and lathe centres is fully described in a new folder by Allegheny Ludlum Steel Corp. Bulletin Gd-92.

Ampco Alloys

A new booklet covering "Ampco Alloys in Pump Service" is being released by Ampco Metal, Inc. Bulletin Gd-175.

Stainless Stock List

The large mill stock of stainless steel bar and wire carried for immediate shipment by the Rustless Iron and Steel Corporation is itemized in a new stock list released by this company. Bulletin Gd-169.

New Pickling Solution

The use of Ferrisul (anhydrous ferric sulfate) for etching of steels and for pickling of stainless steels, copper and copper alloys is explained in detail in a new booklet by the Monsanto Chemical Co. Bulletin Gd-272.

Pure Metals

Pure, carbide-free metals are described and applications suggested in a pamphlet published by Metal & Thermit Corp., who make pure tungsten, chromium and manganese in addition to the ferro-alloys. Bulletin Ma-64.

Moly in Steel

Metallurgists, engineers and production executives who are really interested in the metallurgy of steels and their application will want the excellent book on molybdenum steels published by Climax Molybdenum Company. Bound in loose-leaf manner, this reference book is chock-full of tables which form a volume almost an inch thick. Bulletin Hb-4.

Free Machining Steels

Speed Case and Speed Treat, two steels with increased machining properties, are described in literature available through Monarch Steel Co. Bulletin Cd-255.

Metal Progress, 7301 Euclid Avenue, Cleveland, O.

Send me the literature circled below.

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Page 92		
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ZIRCONIUM Reduces Hot-Tearing Tendencies in Steel Castings . . .

ZIRCONIUM, used in conjunction with calcium-silicon, has been found to be particularly effective as a final deoxidizer in cast steels containing over 0.040 per cent sulphur. The addition of zirconium to such steels minimizes the formation of harmful types of inclusions, and thus substantially reduces the hot-tearing tendencies of these steels and increases their ductility. Zirconium can be added either as 12 to 15 per cent zirconium alloy or as 35 to 40 per cent zirconium alloy for this purpose.

One of our metallurgists will gladly call at your request and explain how you can improve your steel castings with zirconium. He can also help you make more profitable use of the other "Electromet" ferro-alloys—without obligation, of course.

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Items of Interest about other "Electromet" Ferro-Alloys

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Calcium-Silicon Proves an Effective Ladle Deoxidizer — Calcium-silicon used in the ladle combines the action of two powerful deoxidizers. Their effect is rapid and positive. The slag that is formed has a low melting point and a low specific gravity, and hence rapidly frees itself from the molten metal. The result is a cleaner, free-flowing steel.

Medium-Carbon Ferromanganese Produces Better Low-Carbon Steel — The lower carbon content of medium-carbon ferromanganese as compared with the standard grade inhibits the formation and segregation of hard manganese carbide areas in the finished steel. The deoxidizing influence is stronger due to the presence of a small amount of silicon and a lower percentage of iron. Cleaner, more uniform low-carbon steels result.

Vanadium Raises Fatigue Strength of Medium-Manganese Steels — The addition of a small amount of vanadium (about 0.18 per cent) to medium-manganese steels makes it possible to obtain a consistently high endurance ratio.

Silico-Manganese Added to Oxidized Steel — Additions of silico-manganese to an oxidized bath raise the temperature, deoxidize the metal, and limit losses of later additions of other alloys. Silico-manganese treatment produces cleaner, more ductile, better-rolling steel than the use of silicon and manganese alone—at no greater cost.

Calcium-Manganese-Silicon Improves Ductility of Steel Castings — Used as a deoxidizer in the ladle, calcium-manganese-silicon decreases the amount of aluminum sometimes considered necessary to make solid castings poured at high temperatures in green sand molds. Such castings have improved ductility.

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If you want more information about these and the many other "Electromet" ferro-alloys and metals and the service that goes with their purchase, write for the booklet, "Electromet Products and Service."

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CONTRIBUTORS TO THIS ISSUE

IN CASTING ABOUT for an author of an article on the history of rail steel (in keeping with the current celebration of the 75th anniversary of the rolling of the first steel rail in the United States), the Editor happily hit upon the name of **H. H. Morgan.** As manager of the rail and track fastenings department of the Robert W. Hunt Co., Chicago, Mr. Morgan is in charge of activities involving inspection work for more than half of the railroads in the United States, including complete inspection of rails for roads representing 65% of track mileage. Mr. Morgan has been connected with the Robert W. Hunt Co. since 1904, when he was graduated from Lewis Institute with the degree of mechanical engineer. Between 1904 and 1928, when he assumed his present position, he has been consecutively in charge of miscellaneous inspection, manager of the physical testing laboratories, manager of the Hunt cement testing laboratories, Captain in the Ordnance Department, and manager of the Pittsburgh office of his company. Long active in the American Society for Testing Materials, he is now serving as its president. He is a member of the ⛑, American Society of Mechanical Engineers, Western Society of Engineers, and American Railway Engineering Association.

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Philip L. Coddington joined Ludlum Steel Co. in 1925, which was in the pioneer days of stainless applications to process equipment. A graduate of Tufts College in 1917, he entered the Naval Service, took a short war course at Annapolis, and served with the British fleet. He then did engineering sales work in the industrial furnace field. He was with Ludlum Steel Co. from 1925 to 1933, and since then has been connected with sales, engineering and development work in the stainless process equipment field.

G. D. Tranter has been with American Rolling Mill Co. for almost 30 years, as foreman, assistant superintendent and superintendent of the openhearth department, and since 1931 as general superintendent of the Middletown Division. A more detailed account of Mr. Tranter's experience was carried in January when the first portion of his article on the openhearth was published.

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Maxwell Gensamer, associate professor of metallurgy at Carnegie Institute of Technology, is also a part-time member of the staff of the Institute's Metals Research Laboratory. Graduating from Carnegie Tech in 1924 with a B.S. in metallurgy, he worked for five years as metallurgist for the Page Steel and Wire Co. plant of American Chain Co., before returning to his alma mater. Working in the Metals Research Laboratory, he received his D.Sc. degree in 1933. He was appointed assistant professor of metallurgy in 1935 and associate professor in 1938.

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Mechanisms of wear and their industrial significance form **Russell W. Dayton's** research assignment at Battelle Memorial Institute, Columbus, Ohio. He has been a member of Battelle's technical staff ever since leaving Rensselaer Polytechnic Institute in 1934, where he received his undergraduate degree, followed by master's and doctor's degrees. Dr. Dayton, an ⛑ member, is the author of an extended abstract on metals and lubricants for bearings and gears. Included among his other published articles are two based upon his excellent research on silver-rich alloys for bearings, which show so much promise, particularly for use in airplane engines. Golf and frolics with his beautiful German shepherd are his chief hobbies.

H. H. Morgan

Maxwell Gensamer

G. D. Tranter

Russell W. Dayton

Nitriding Equipment...

STILL GOOD AFTER 6 YEARS' SERVICE

(left) *Bell type furnace hood (on crane hook) of Inconel used in Nitriding. (Courtesy — Westinghouse Electric & Mfg. Company.)*

(below) *Basket of Inconel used in Pit Type Nitriding furnace. (Courtesy—Westinghouse Electric & Mfg. Company.)*

Containers and separating screens made of Inconel, stand up against heat and corrosion

EXCEPTIONALLY suitable for nitriding equipment is the heat and corrosion resistant alloy, Inconel. Containers of Inconel like those illustrated have been used as long as six years . . . and still good for further service.

Screens for separating small parts during nitriding are also made of Inconel, in the form of expanded metal or wire cloth. Such screens permit free access of gases to all parts. Tubing employed for conveying ammonia gas into containers is also made of Inconel or Pure Nickel.

Write for further information on use of Inconel for nitriding equipment. Ask also for Bulletins T-7, "Properties and Uses of Inconel" and T-8, "The Welding of Inconel." Address:

THE INTERNATIONAL NICKEL COMPANY, INC.
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Inconel is a registered trade-mark of The International Nickel Company, Inc., which is applied to a nickel alloy containing approximately 80% Nickel with additions of chromium and iron.

ADVANTAGES OF INCONEL AT HIGH TEMPERATURES

1. High strength and ductility maintained.
2. Makes ductile welds, not subject to intergranular deterioration.
3. Free from excessive distortion during sudden temperature changes, due to low coefficient of thermal expansion.
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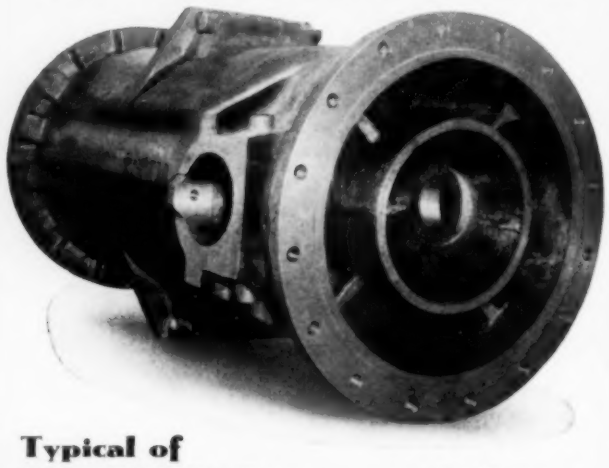
5. Highly resistant to a wide range of corrosive conditions.
6. Very resistant to oxidation, even at high temperatures. Oxide adherent and does not scale off.
7. Can be formed readily into complicated shapes.
8. Mill forms and welding rod available from mill stocks.

INCONEL

DURALOY

2400 lb. CHROME-NICKEL CASTING



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DURALOY Service to Industry

This rather intricate casting implies extensive experience in stainless steel which, in fact, dates back to 1922. It also implies complete production facilities such as electric furnaces of various sizes, heat-treating furnaces, pickling tanks, machine shop, etc.

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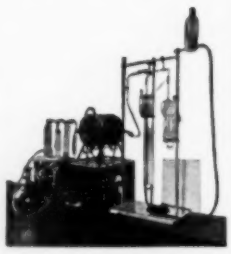

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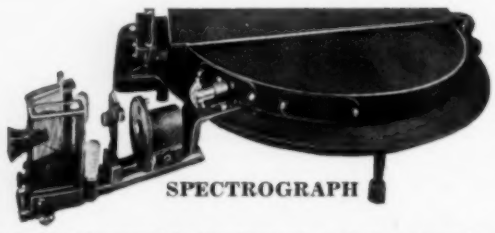

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A R L Spectrographic Equipment is fast, accurate and most modern. It makes qualitative analysis for stray elements easy and certain. Qualitative analysis for presence of seventy elements made in eight minutes. Quantitive analysis of, for example, six elements made in four additional minutes.

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SORBY'S PIONEERING

(Starts on page 45) result Dr. PERCY, the President, and Sir HENRY BESSEMER were commissioned to act with Dr. SORBY in deciding on the best means of illustrating a comprehensive paper on these new metallographical discoveries. The result was the paper printed in the *Journal* in 1887 and illustrated by six plates containing photographs reproduced by the Woodburytype* process. Four constituents — pure iron, graphite, the pearly constituent and the definite compound of iron and carbon — were positively identified and described in this memoir while others were indicated with less certainty.

Whether the interest mentioned above had meanwhile waned, or whether there was lack of time owing to the lengthy discussion of other papers, it is unfortunately a fact that this really epoch-making paper was "taken as read" and was not even discussed "by correspondence". With its publication, however, SORBY's active participation in the investigation of the microstructure of iron and steel practically ceased. Apparently he occasionally lectured on the subject but no record has been found of further researches. When ARNOLD was appointed to the Chair of Metallurgy at Firth College, Sheffield, in 1889, he asked SORBY to resume his investigations so as to correlate microstructure with thermal, mechanical and chemical features which were then being investigated. SORBY's eyesight was failing, however, and he was deeply engaged in other work, so he declined but he showed ARNOLD his methods and lent him his specimens which were afterwards bequeathed to the College.

The subsequent development of metallography, from the foundations he had so carefully and accurately laid, he left to others.

*In the article in METAL PROGRESS it was stated in error that there were "photographic prints" pasted individually into each copy of the *Journal*. The Woodburytype process actually used is no longer practiced by engravers. A contact print is made on a thick film of light-sensitive gelatine, developed and hardened. It now contains the image in relief, and is pressed into a smooth metal plate, leaving an intaglio impression. Liquid gelatine ink is worked into the plate, and non-absorbent paper pressed on; after the gelatine has set, the paper to which the ink clings is removed, and the image dried in alum.